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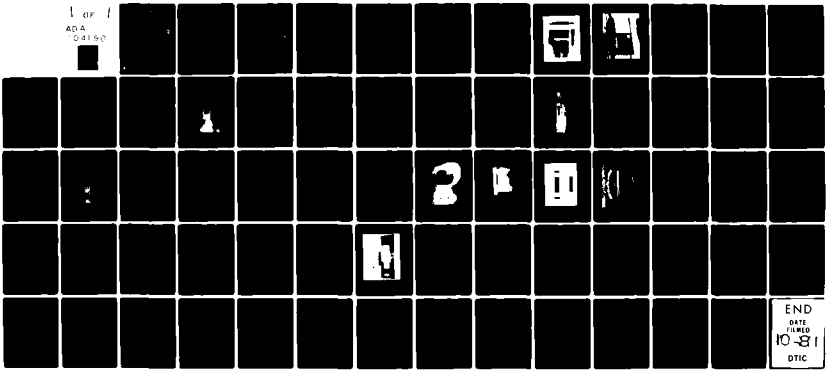

LEVEL II

AFGL-TR-81-0181

DEVELOPMENT OF LARGE CYLINDRICAL STRIPLINE ANTENNA ARRAYS

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AD A104190

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Final Report for Period February 1978 - January 1981

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stripline	S-Band	Electrically small antennas
Antenna	Cylindrical antenna arrays	Corporate harness
Array	Encapsulated antennas	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Physical Science Laboratory, New Mexico State University has conducted research and development studies of antenna designs under contract to the Air Force Geophysics Laboratory. The studies included the development stripline telemetry antenna arrays for large diameter missiles. Electrically small antennas at 550 MHz. Encapsulated S-Band antennas for small spherical satellites.

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1.0 INTRODUCTION

This is the final report for the contract period from February 1978 to January 1981.

The authors wish to thank J. E. Litton, R. Lanphere and other members of the Physical Science Laboratory (PSL), Antenna Technology Section, who contributed to the work reported herein.

2.0 ANTENNA DEVELOPMENT

2.1 Overview

During the report period several stripline antennas were developed for large diameter vehicles. All of the antennas have a number of features in common and in order to avoid repetitive descriptions those features will be outlined here and the differences will be discussed in the sections pertaining to the particular antenna models.

The unit element common to all arrays is a stripline slot antenna. The array is formed by feeding a number of slots with a stripline corporate harness which terminates at the center junction into an SMA coaxial launcher. The constraints on the harness lengths are that the sections between junctions be multiples of half wavelengths and that the slots be all fed in phase. The optimum design is the one that meets the above constraints and has a minimum harness width. The number of arrays used for a particular vehicle is determined by the vehicle diameter. If more than one array is used the arrays are fed by coaxial cable from a common junction.

2.2 The Model 55.205 Antenna

The Model 55.205 antenna was designed to be used with a 17.2 inch diameter vehicle. The antenna is illustrated in Figure 1 through 4. The total array consists of two eight element and one four element sub-arrays. The sub-arrays are fed through a printed circuit power divider and coaxial harness. The power divider was specially designed for this array and carries the *designation* PSL PWD 205. The antenna is mounted in a recess of the vehicle and its surface is flush with the O.D. of the vehicle.

2.3 The Model 55.1405 Antenna

The Model 55.1405 *antenna was designed* for a 14 inch diameter vehicle. The antenna is illustrated in Figures 9 and 10. It consists of two subarrays of 8 elements each. The antenna surface is flush with the O.D. of the vehicle.

2.4 The Model 55.1505 Antenna

The Model 55.1505 antenna was designed for a 15 inch diameter. It is very similar to the model 55.1405 antenna described in Section 2.3, except that the spacing between unit elements was increased to accommodate the larger vehicle diameter. Since the spacing was only increased by 0.038λ at 2.25 GHz it had no significant effect on the radiation pattern.

2.5 The Model 55.2005 Antenna

The Model 55.2005 antenna was designed for a 20 inch diameter vehicle. The antenna is illustrated in Figures 21 and 22. Three arrays with eight elements each are required for the 20 inch diameter vehicle. It should be noted that in Figure 24 the two antenna arrays shown at either end of the vehicle extension are independent antennas that operate at different frequencies.

2.6 The Ten Inch Diameter Sphere

The two antennas were designed for the sphere. The antenna for the S-Band frequency is the Model 55.511 stripline slot array. The 550 MHz frequency antenna is a two element array of Model 67.006 printed circuit transmission line antennas. The antennas are mounted on a 9 inch diameter cylinder which becomes part of the sphere. The spherical surface is obtained by encapsulating the antennas in FPH foam. To obtain a smooth surface the foam is filled with latex paint and is then sprayed with plasite paint. The antennas are illustrated in Figures 27 through 30.

2.7 The Model 67.004 Antenna

The Model 67.004 antenna is very similar to the Model 67.006 antenna described in Section 2.6. It differs only in size since it was designed for a 409 MHz operating frequency.

3.0 STRIPLINE ANTENNA FABRICATION PROCEDURE

The procedure for fabrication is the same for all models. After the harness has been designed, the amberlith master is cut and is used for photo-etching the printed circuit board. The material used is K-6098 teflon-fiber-glass, .060 thick, copper-clad board manufactured by the 3M Company. The slots and the harness are photoetched on opposite sides of the same board which is then glued to a second board from which the copper has been removed on one side of the board. During the gluing process, which requires both heat and pressure, the antenna is also shaped to the approximate vehicle diameter. The array is then trimmed to the correct dimensions and the holes that constitute the cavity walls are drilled. The feed connector is attached and the antenna is copper plated. After the copper plating the antenna receives a preliminary performance test after which it is nickel plated. The final tests are performed with the antenna mounted on a mockup or flight vehicle extension for impedance and radiation pattern measurements.

Figure 1. Model 55.205 stripline antenna mounted on a 17.2 inch diameter vehicle extension.

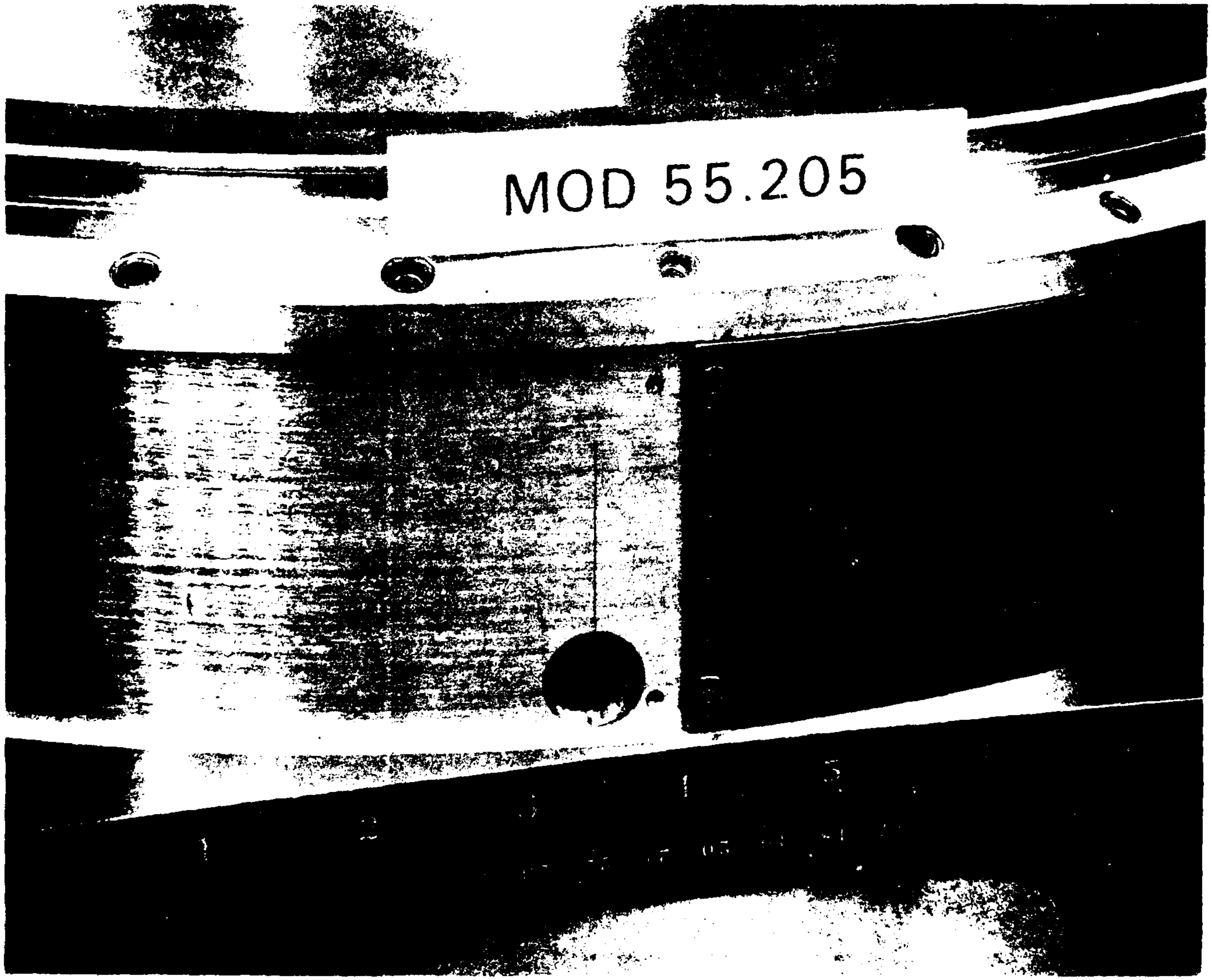


Figure [illegible]. Detail showing [illegible] partially mounted.

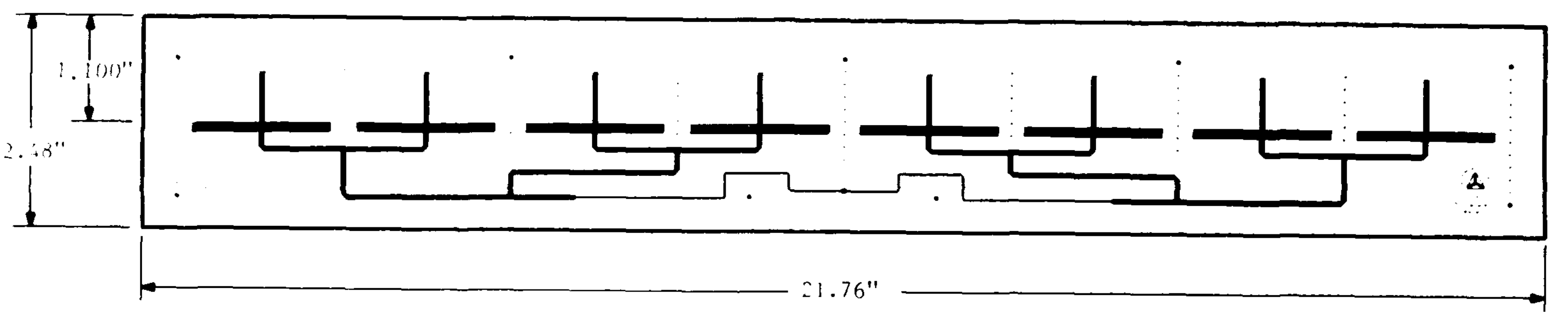


Figure 3. X-Ray view of the Model 55.205 Antenna.

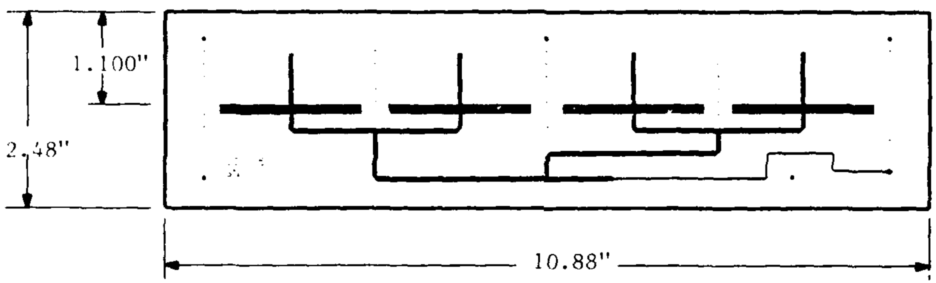


Figure 4. X-Ray view of the Model 55.205.5 Antenna.

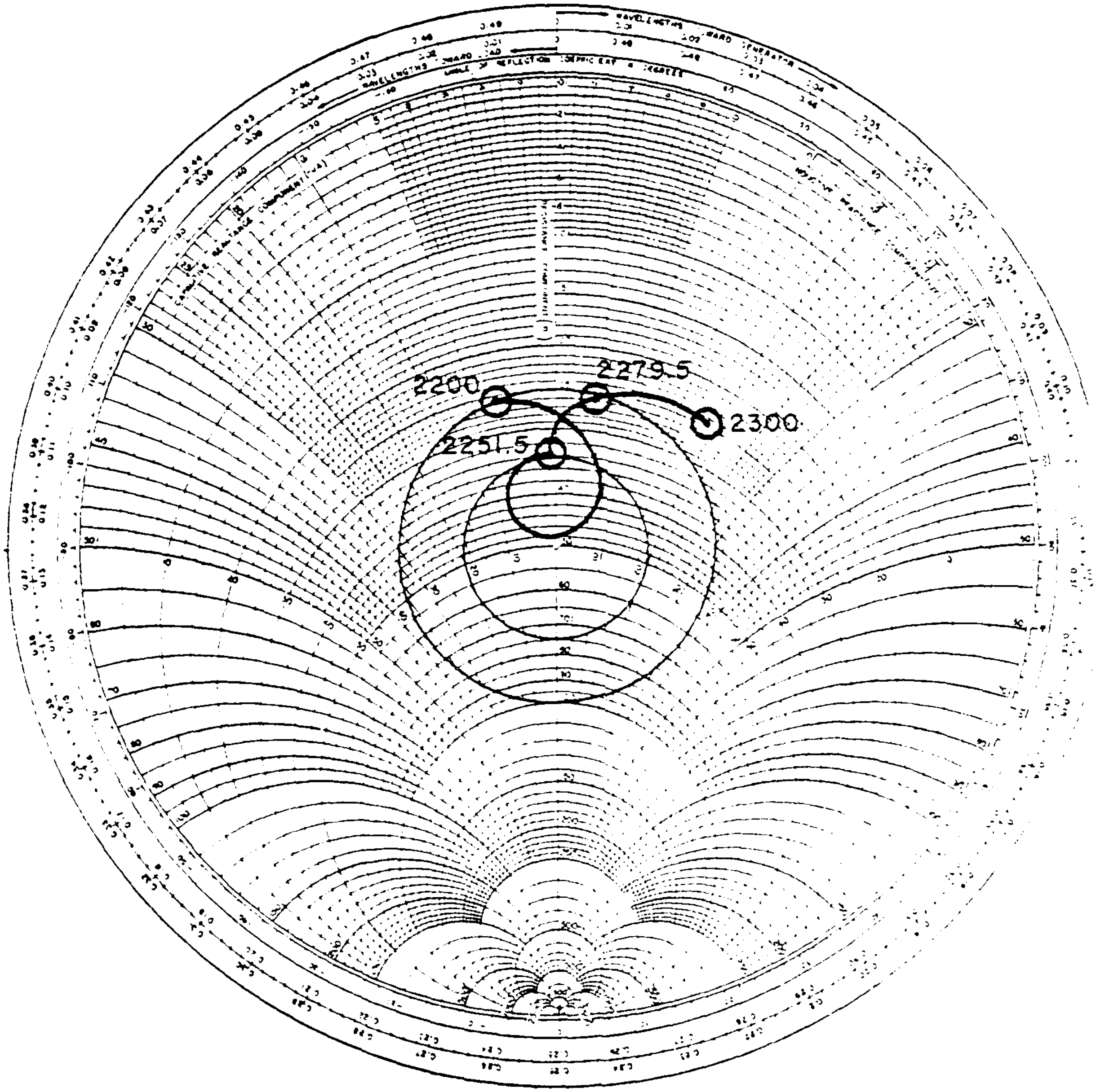


Figure [illegible]. Impedance versus frequency chart for the Model [illegible] [illegible] element array.

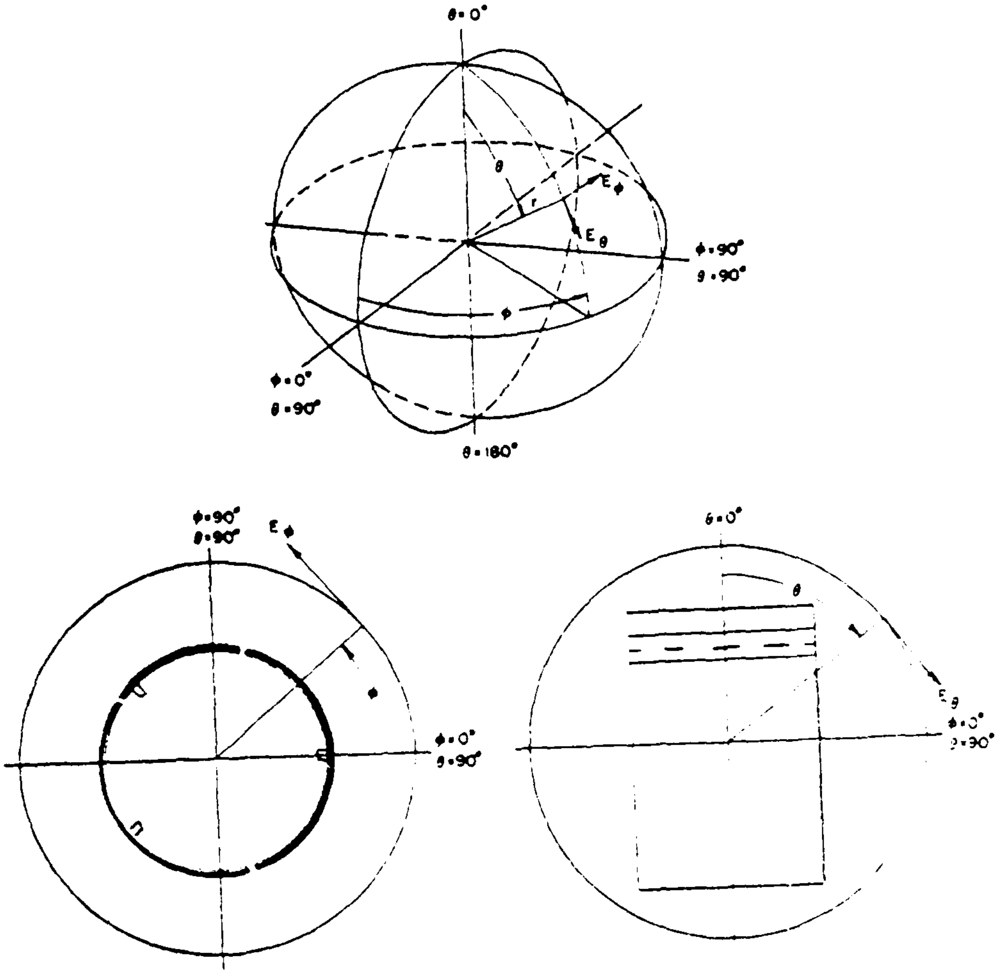


Figure 6. Coordinates for the Model 55.205 and 55.205.5 pattern Measurements. Range Request No. 2-50.

POLARIZATION

- X GAIN REF
- X Eθ
- Eφ
- R.C.
- L.C.
- OTHER AS NOTED UNDER REMARKS.

φ = ___ ° θ = 0 °

COORDINATE REFERENCE

φ = 0 °
θ = 90 °

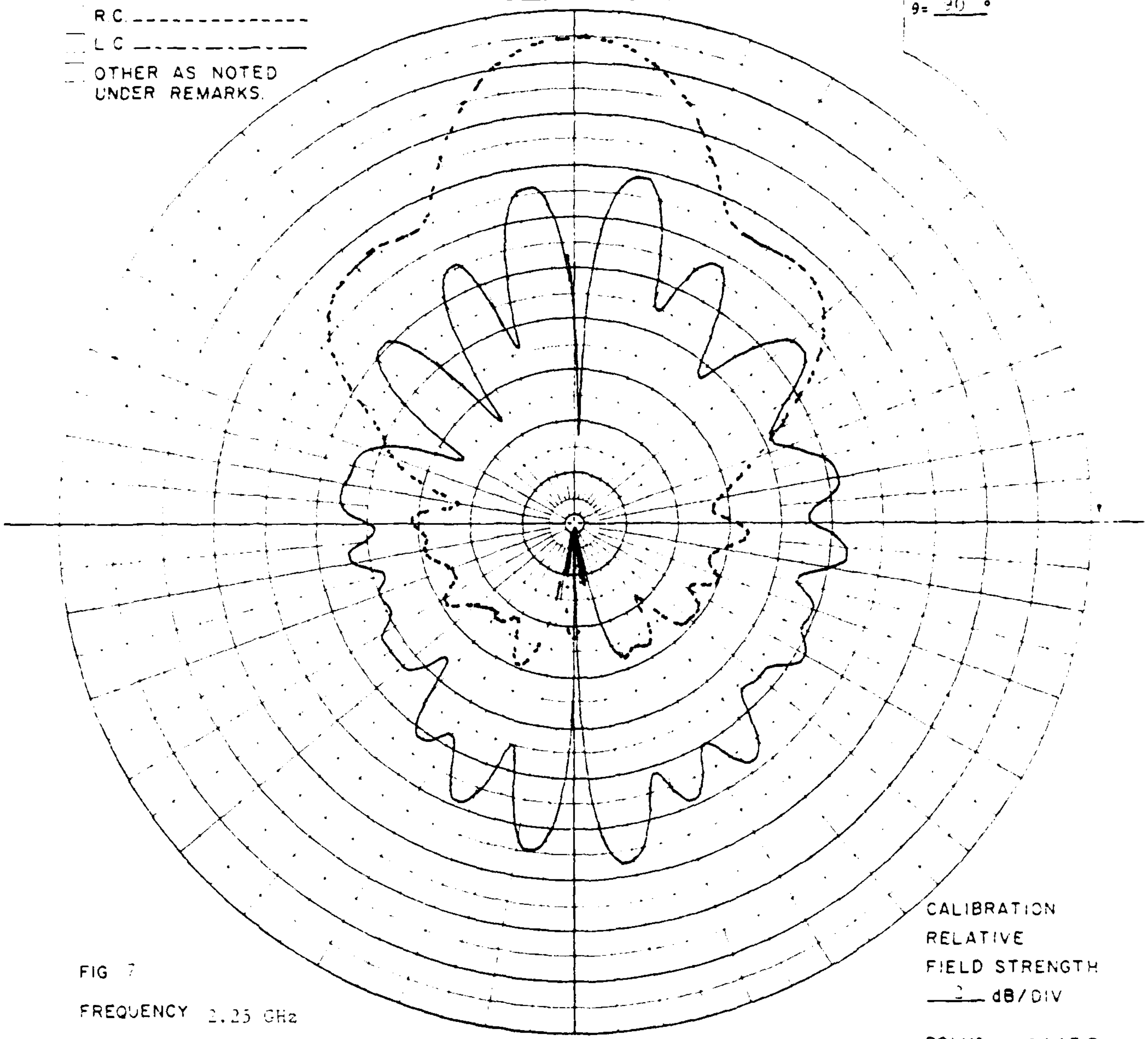


FIG 7

FREQUENCY 2.25 GHz

ANTENNA Model 55.205

REMARKS The gain of the reference antenna is 16 dBi

CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV

PSL№ 12145 S
R.R. 2-80

POLARIZATION

- GAIN REF
- Eθ
- Eφ
- R.C.
- L.C.
- OTHER AS NOTED UNDER REMARKS.

ϕ = 0 ° θ = 90 ° COORDINATE REFERENCE ϕ = 90 ° θ = 90 °

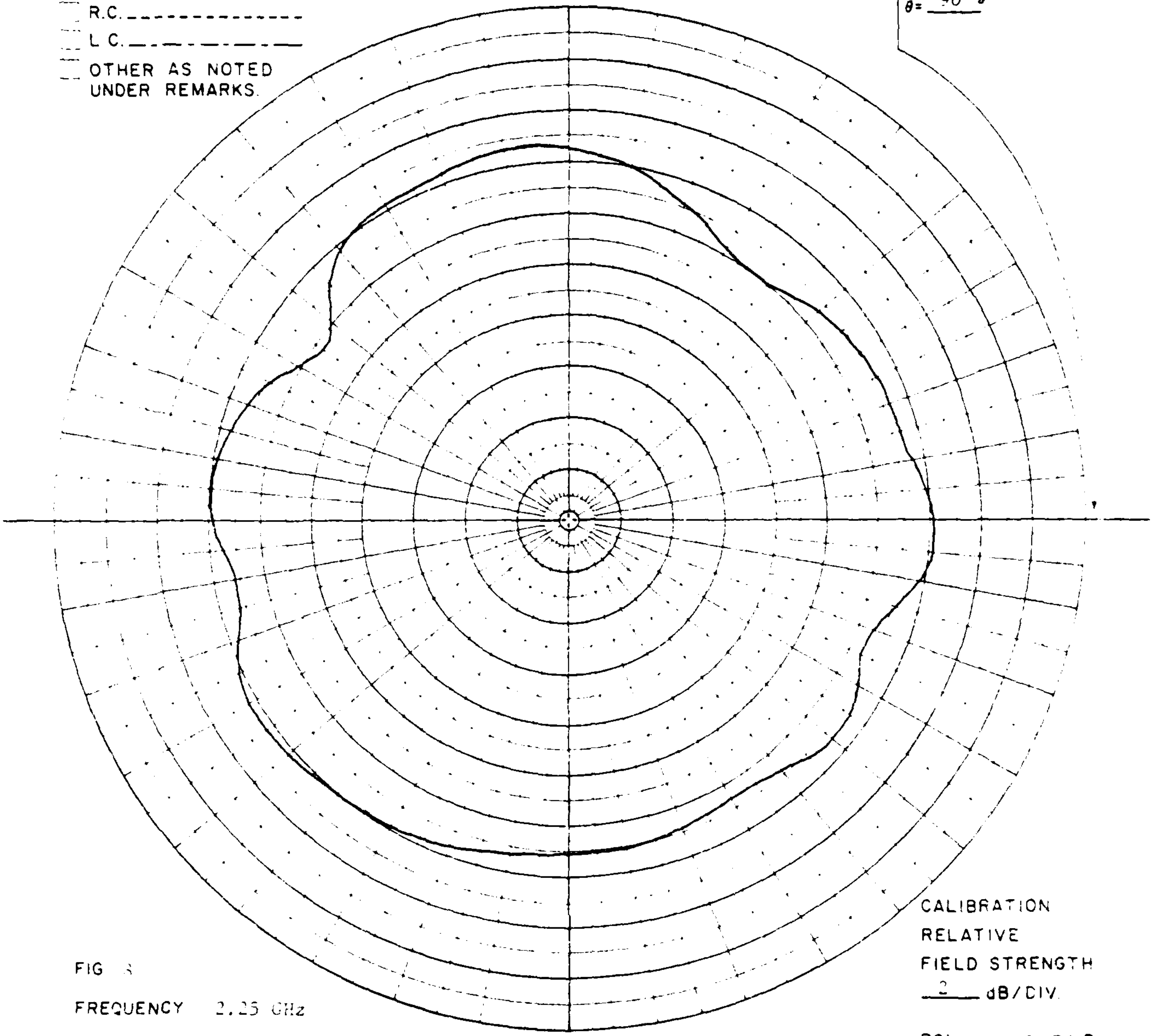


FIG 8

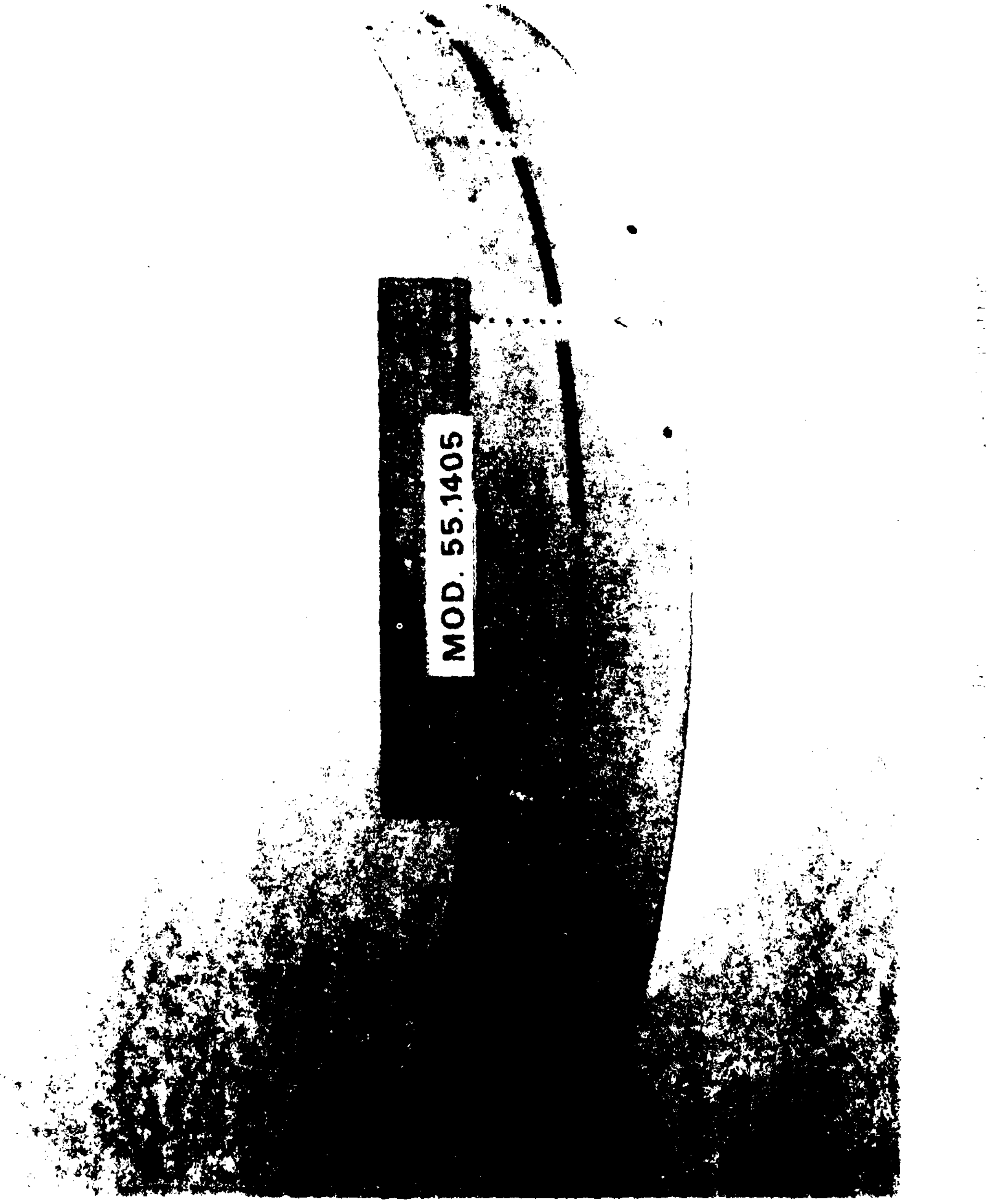
FREQUENCY 2.25 GHz

ANTENNA Model 55.205

REMARKS

CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

PSL № 121509
R.R. 2450


MOD. 55.1405

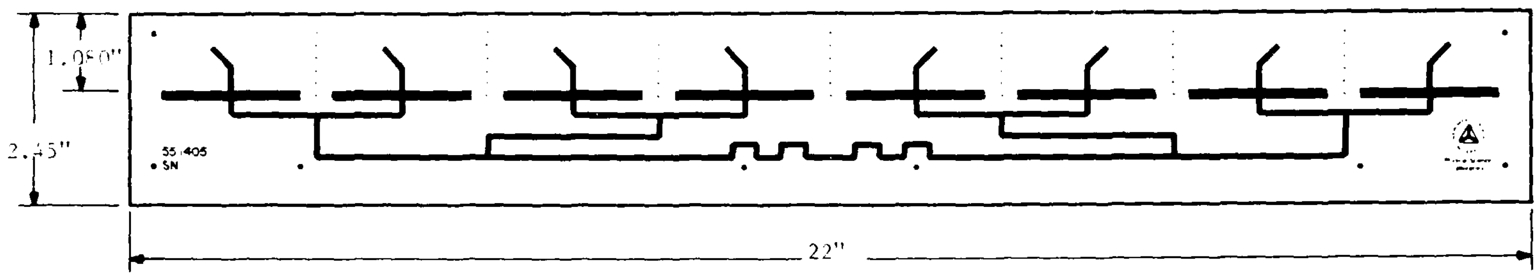


Figure 10. X-Ray view of the Model 55.1405 Antenna.

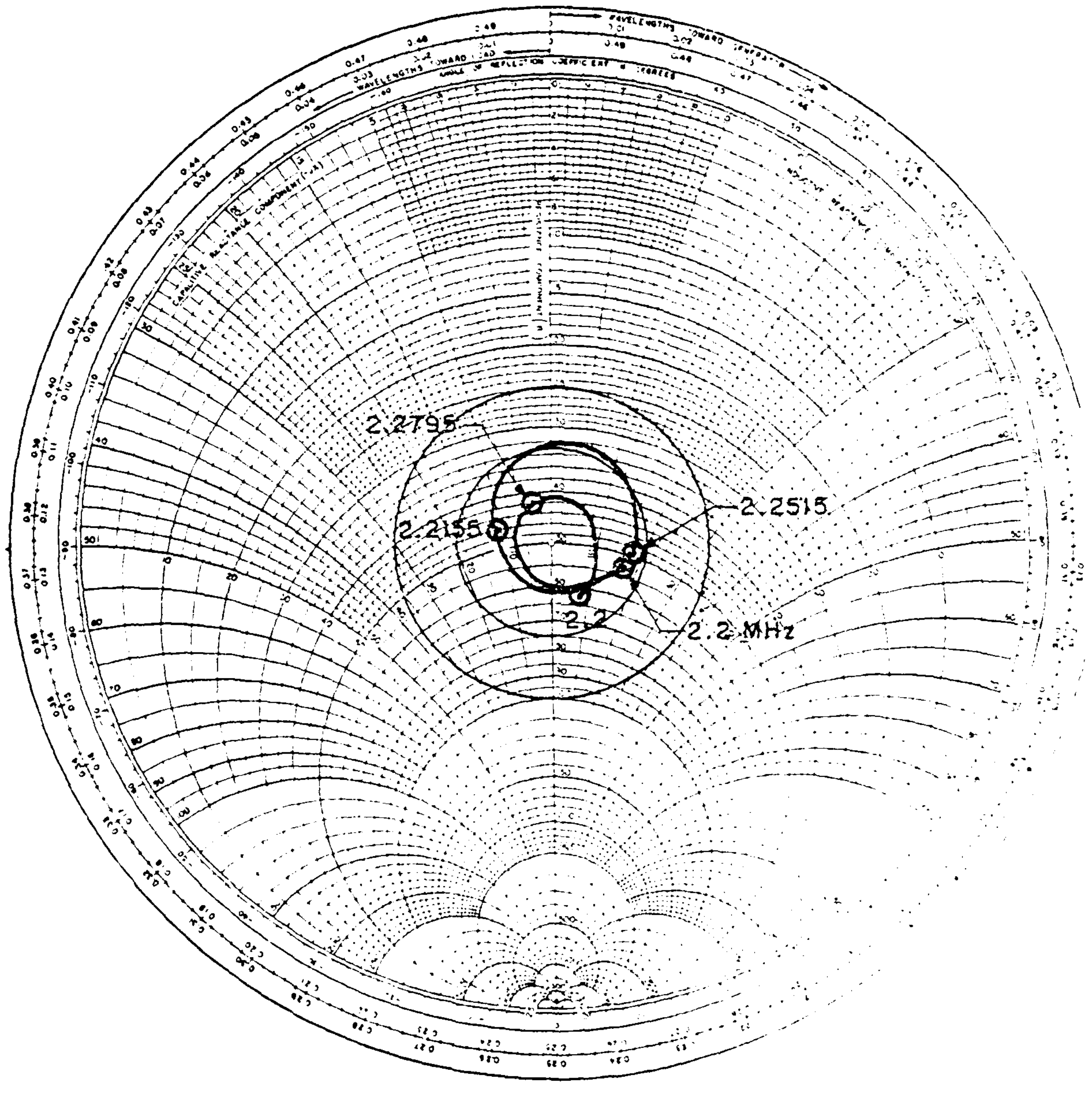


Figure 11. Impedance versus frequency curve for the [illegible]

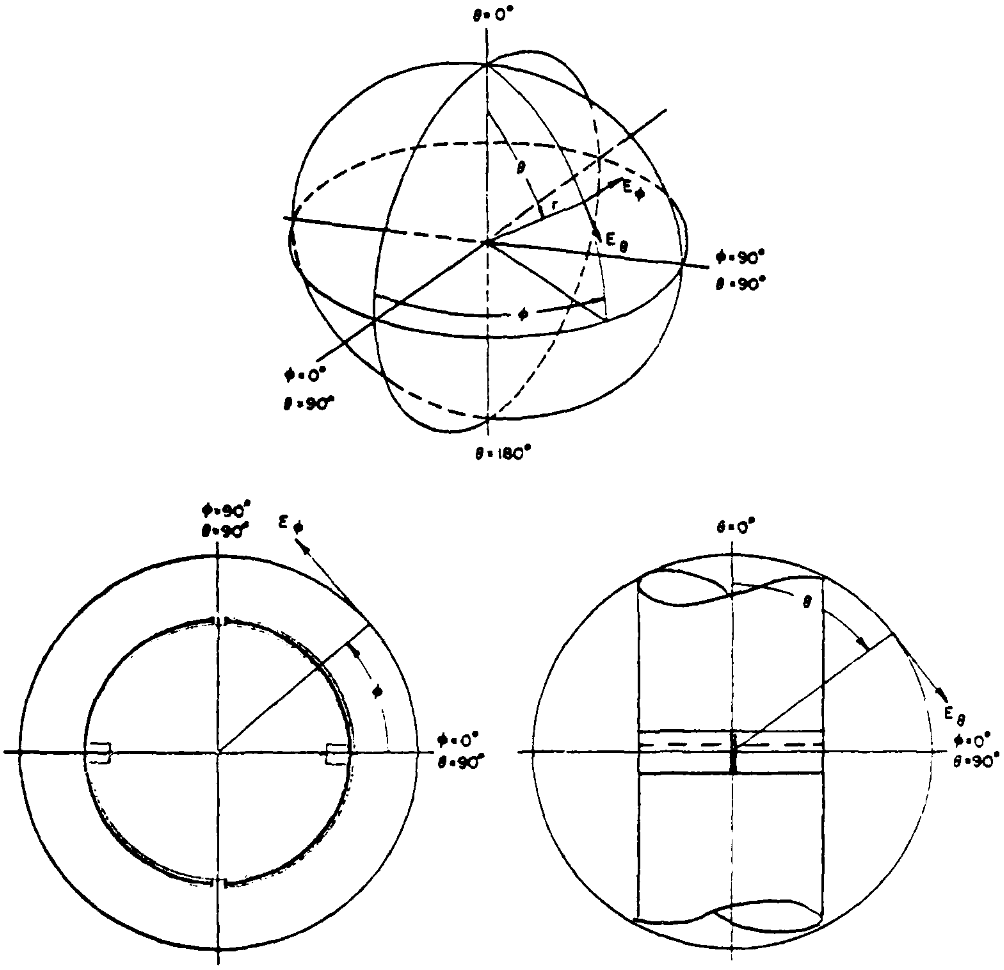


Figure 12. Coordinates for the Model 55.1405 pattern measurements. Range Request No. 2549.

POLARIZATION

[X] GAIN REF. - - - - - - - - -

[X] Eθ ______________

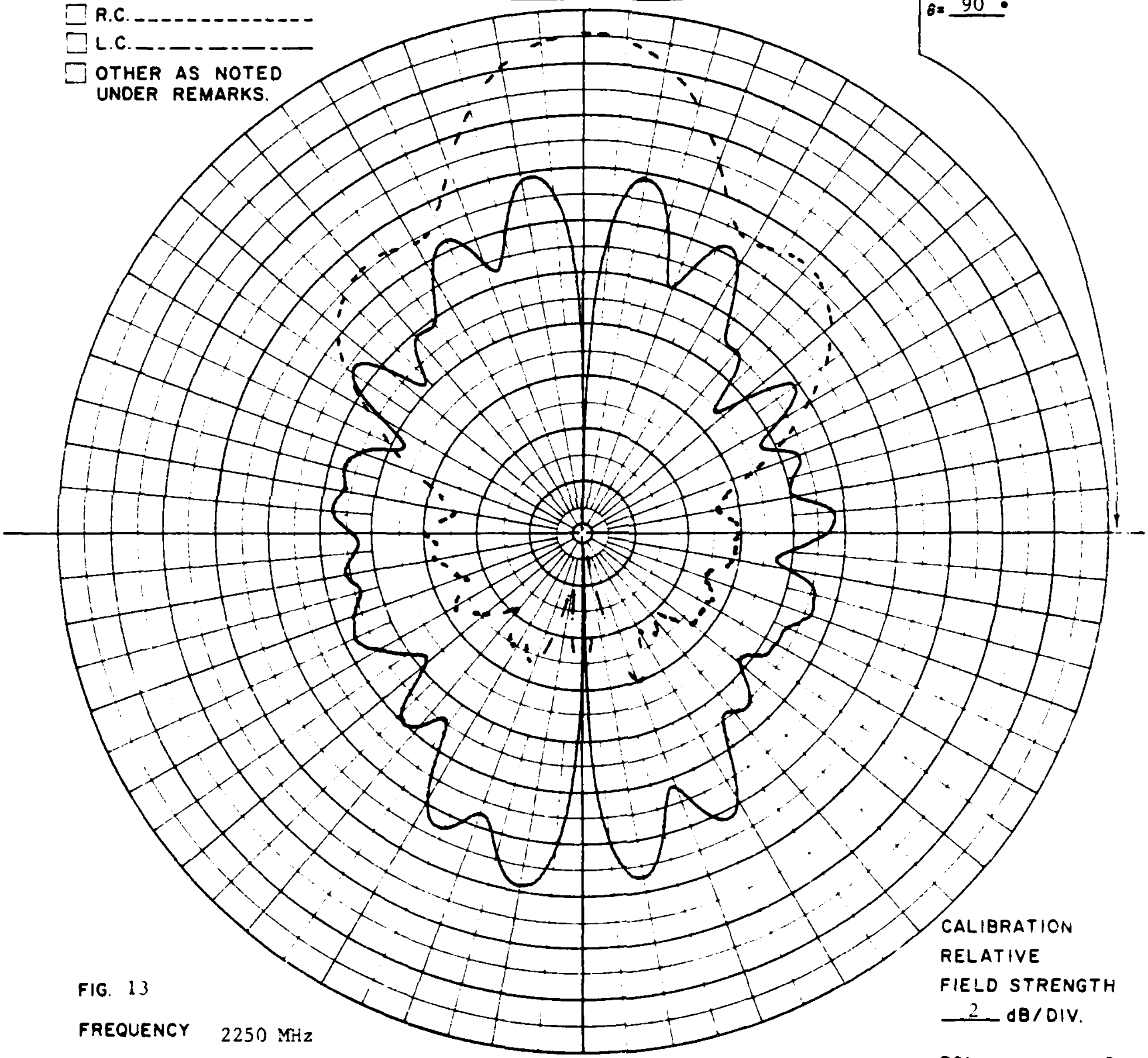
[ ] Eϕ - - - - - - - - - -

[ ] R.C. - - - - - - - - - - - - -

[ ] L.C. — - — - — - —

[ ] OTHER AS NOTED UNDER REMARKS.

ϕ = ____ ° θ = 0 ° COORDINATE REFERENCE ϕ = 0 ° θ = 90 °



CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

FIG. 13

FREQUENCY 2250 MHz

ANTENNA Mod. 55.1405

REMARKS The gain of the reference Antenna is 16 dBi

PSL № 17003B
R.R. 2549

POLARIZATION

- [ ] GAIN REF.
- [x] Eθ
- [ ] Eϕ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED UNDER REMARKS.

ϕ = 0° θ = 90° COORDINATE REFERENCE

ϕ = 90°
θ = 90°

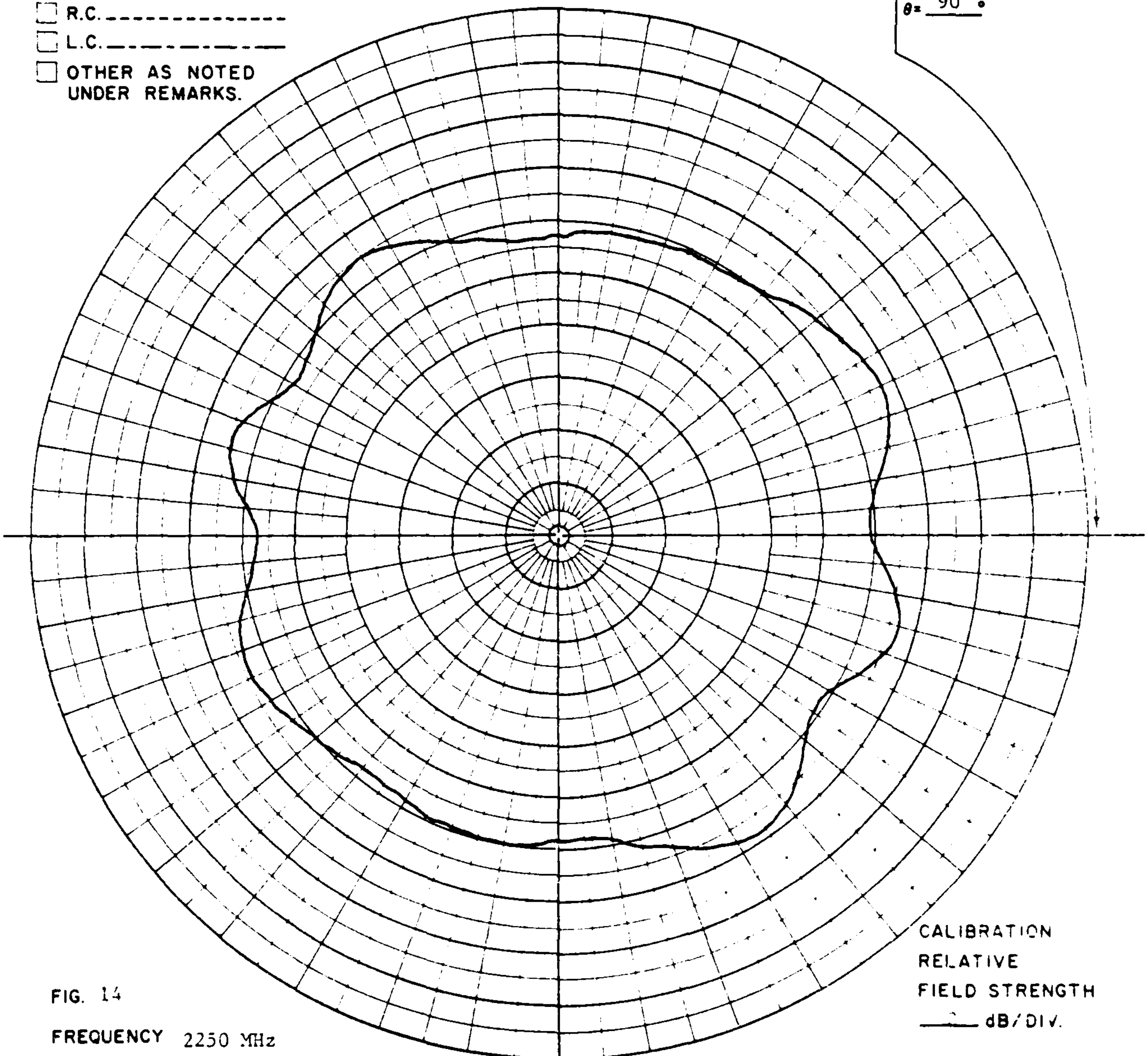


FIG. 14

FREQUENCY 2250 MHz

ANTENNA Mod. 55.1405

REMARKS

CALIBRATION
RELATIVE
FIELD STRENGTH
[illegible] dB/DIV.

PSL № 17009B
R.R. 2549


MOD. 55.1505

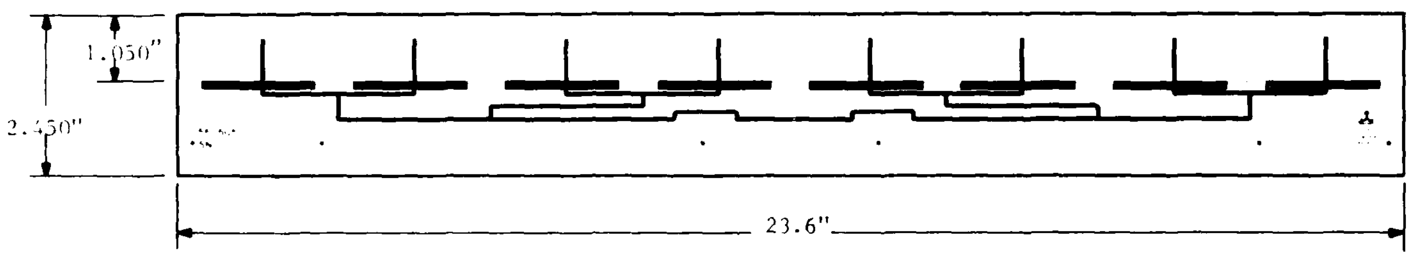


Figure 16. X-Ray view of the Model 55.1505 Antenna.

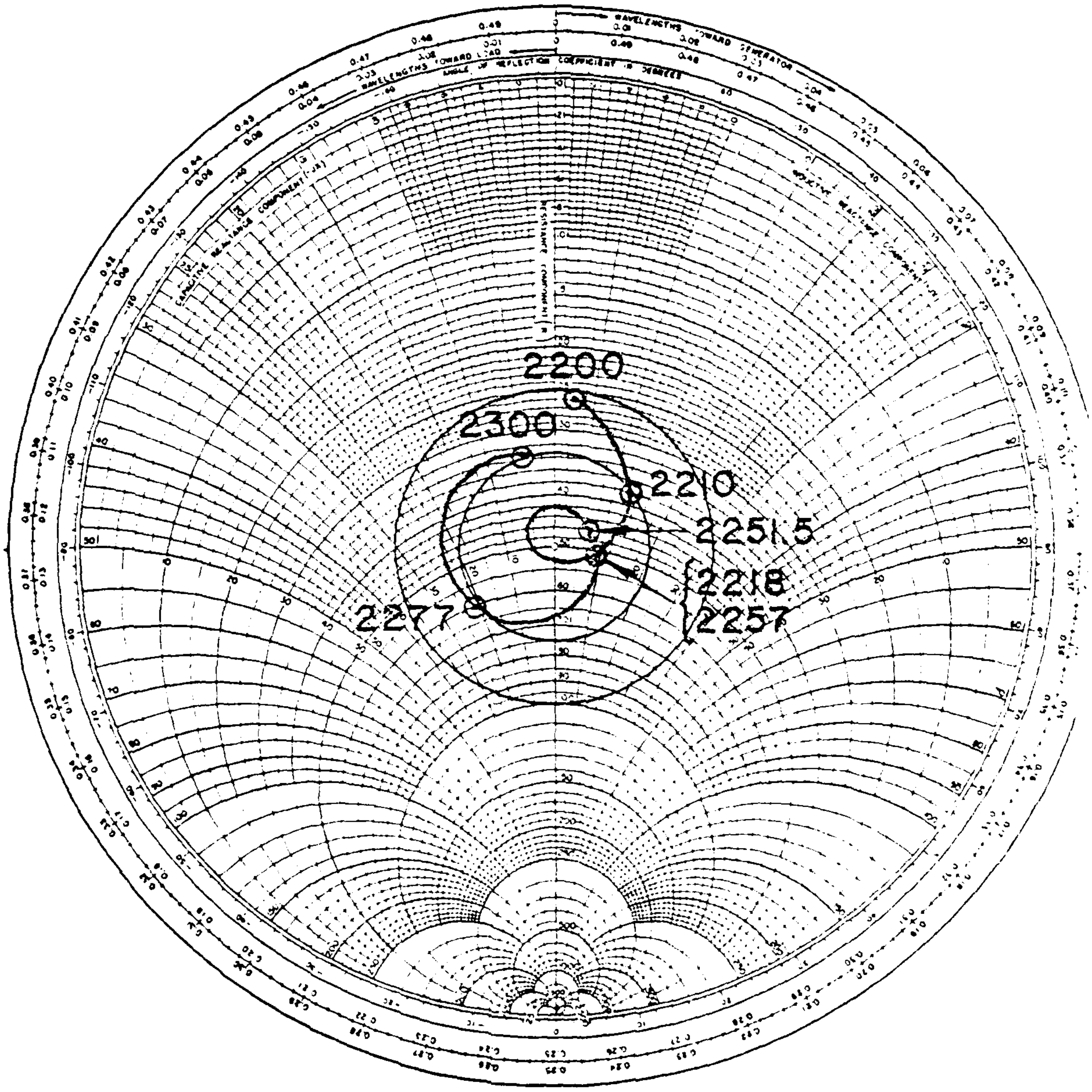


Figure 17. Impedance versus frequency curve for the Model 55.1505.

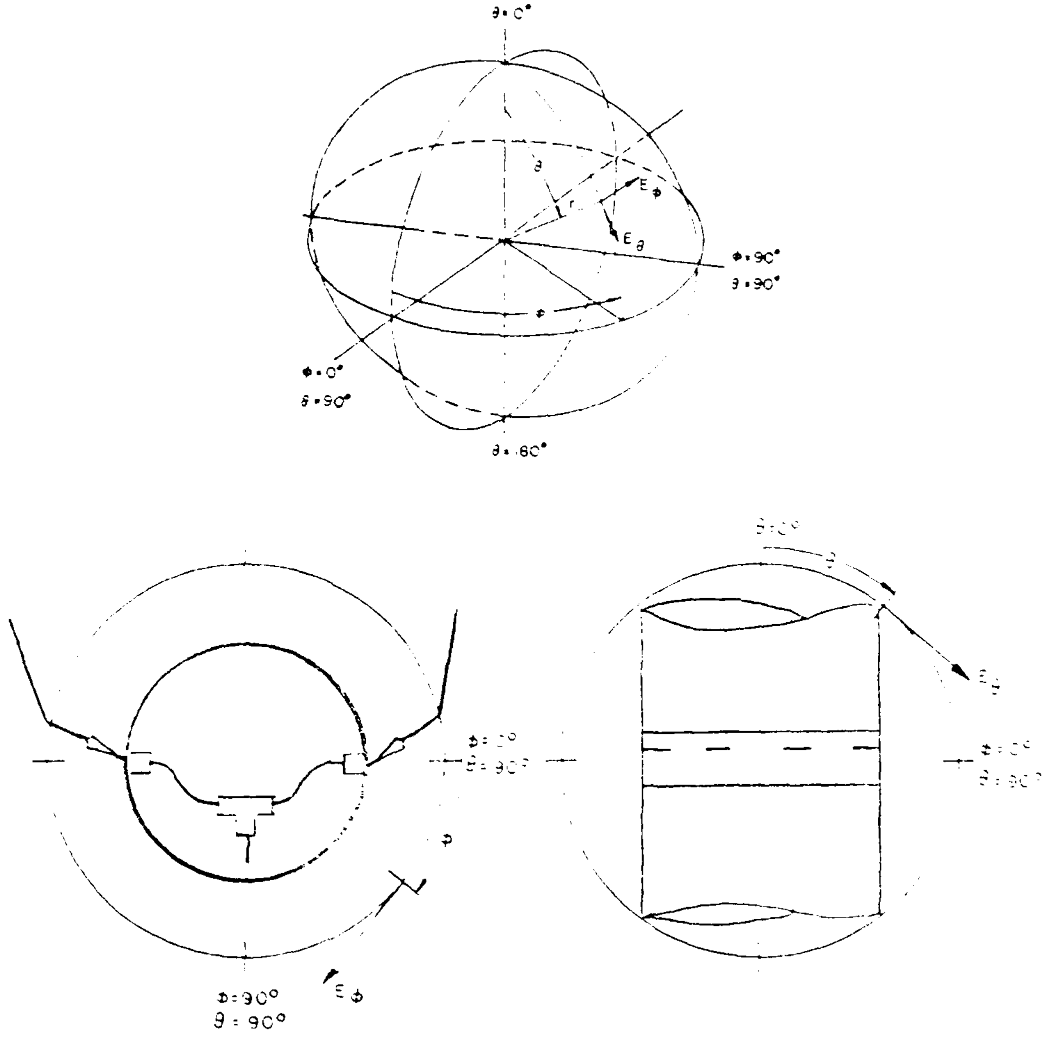


Figure 18. Coordinates for the Model 55.1505 patterns.
Range Request No. 2550.

POLARIZATION

[X] GAIN REF. - - - - - -

[X] Eθ ————

[ ] Eφ — — — — —

[ ] R.C. - - - - - -

[ ] L.C. — - — - —

[ ] OTHER AS NOTED UNDER REMARKS.

φ = ____ ° θ = 0 ° COORDINATE REFERENCE

φ = 0 °
θ = 90 °

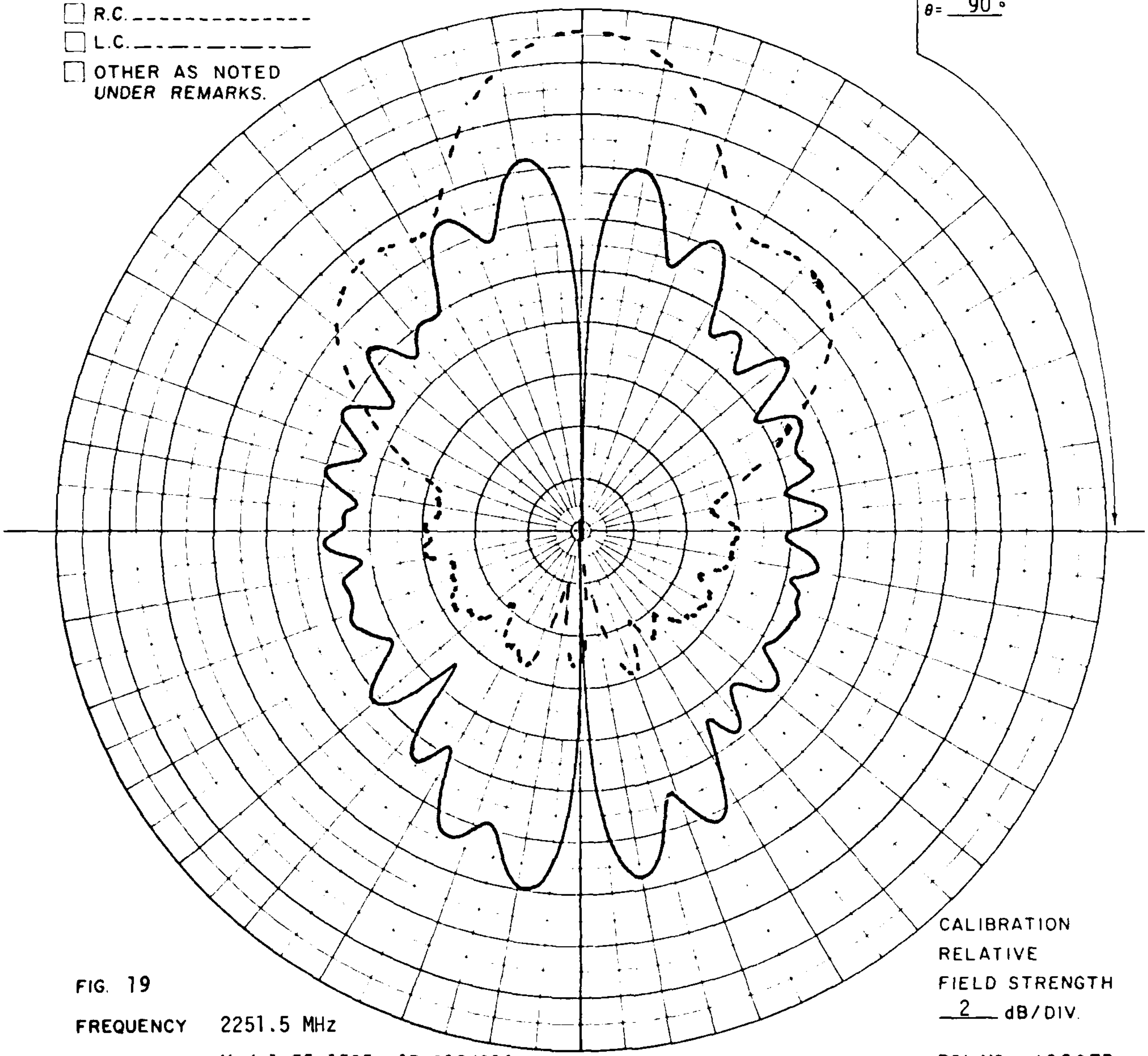


FIG. 19

FREQUENCY 2251.5 MHz

ANTENNA Model 55.1505, AD 913/914

REMARKS The gain of the reference antenna is 16 dBi

CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

PSL № 16227B

RR 2550

POLARIZATION

- [ ] GAIN REF.
- [x] Eθ
- [ ] Eφ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED UNDER REMARKS.

φ = 0° θ = 90° COORDINATE REFERENCE φ = 90° θ = 90°

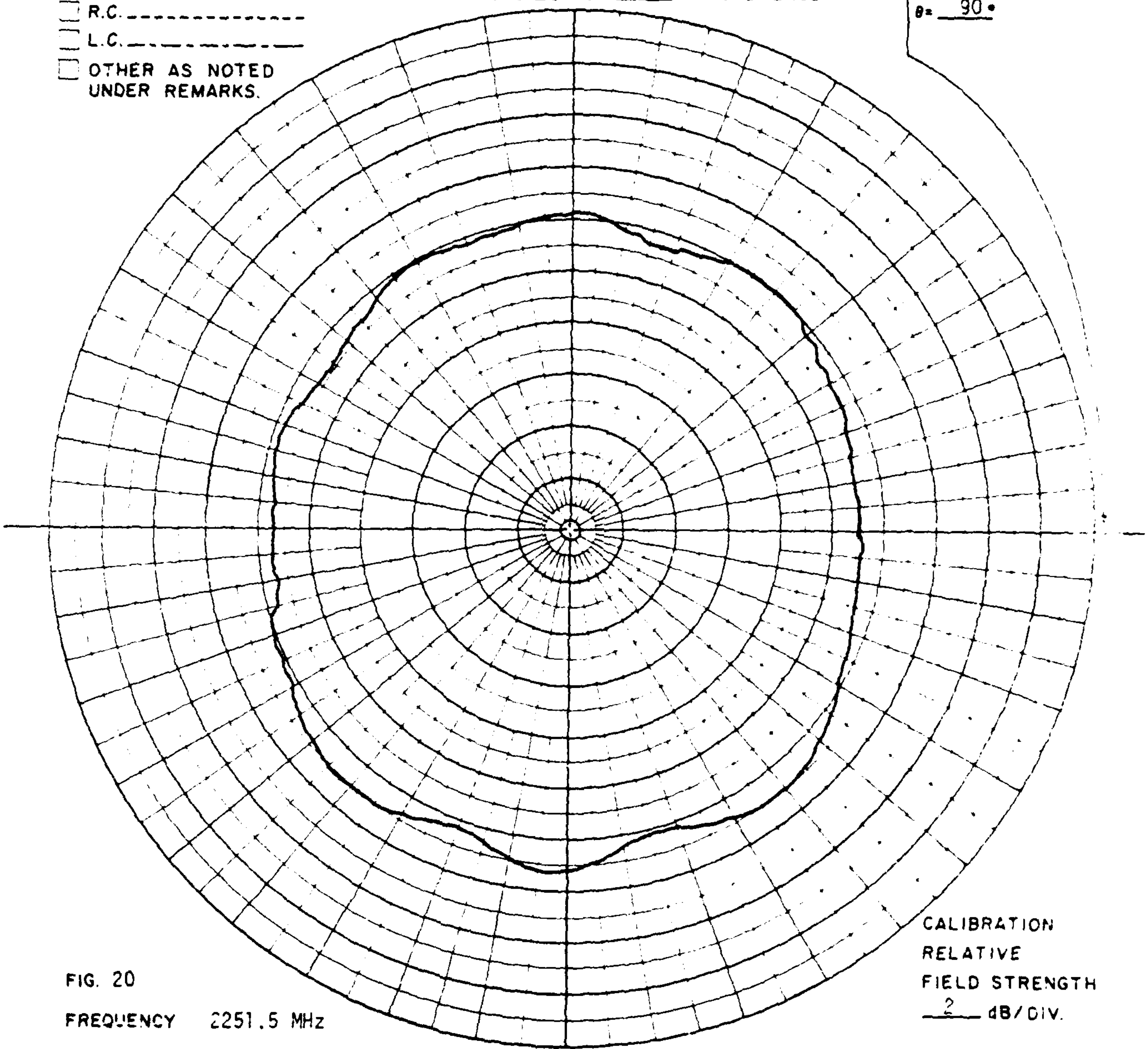


FIG. 20

FREQUENCY 2251.5 MHz

ANTENNA Model 55.1505, AD 913/914

REMARKS

CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

PSL № 162338

RR 2550

Figure 21. View of the Model 55.2005 Subarray.

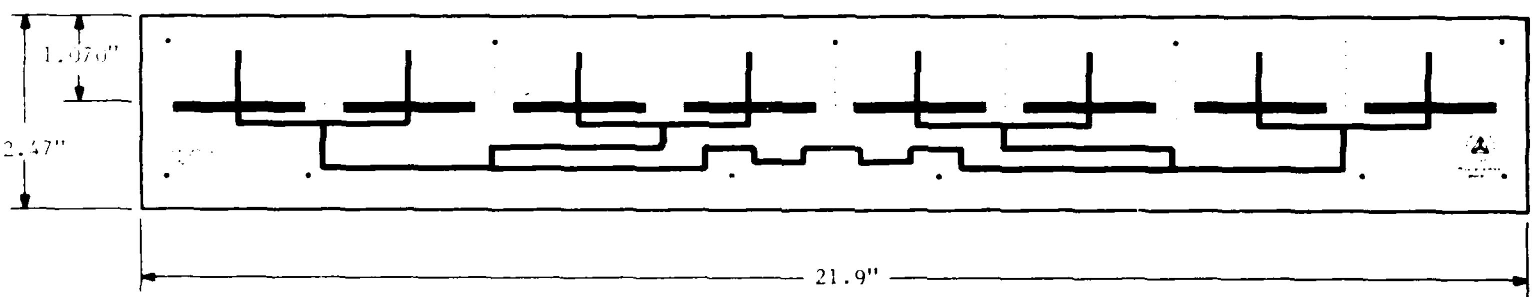


Figure 22. X-Ray view of the Model 55.2005 Antenna.

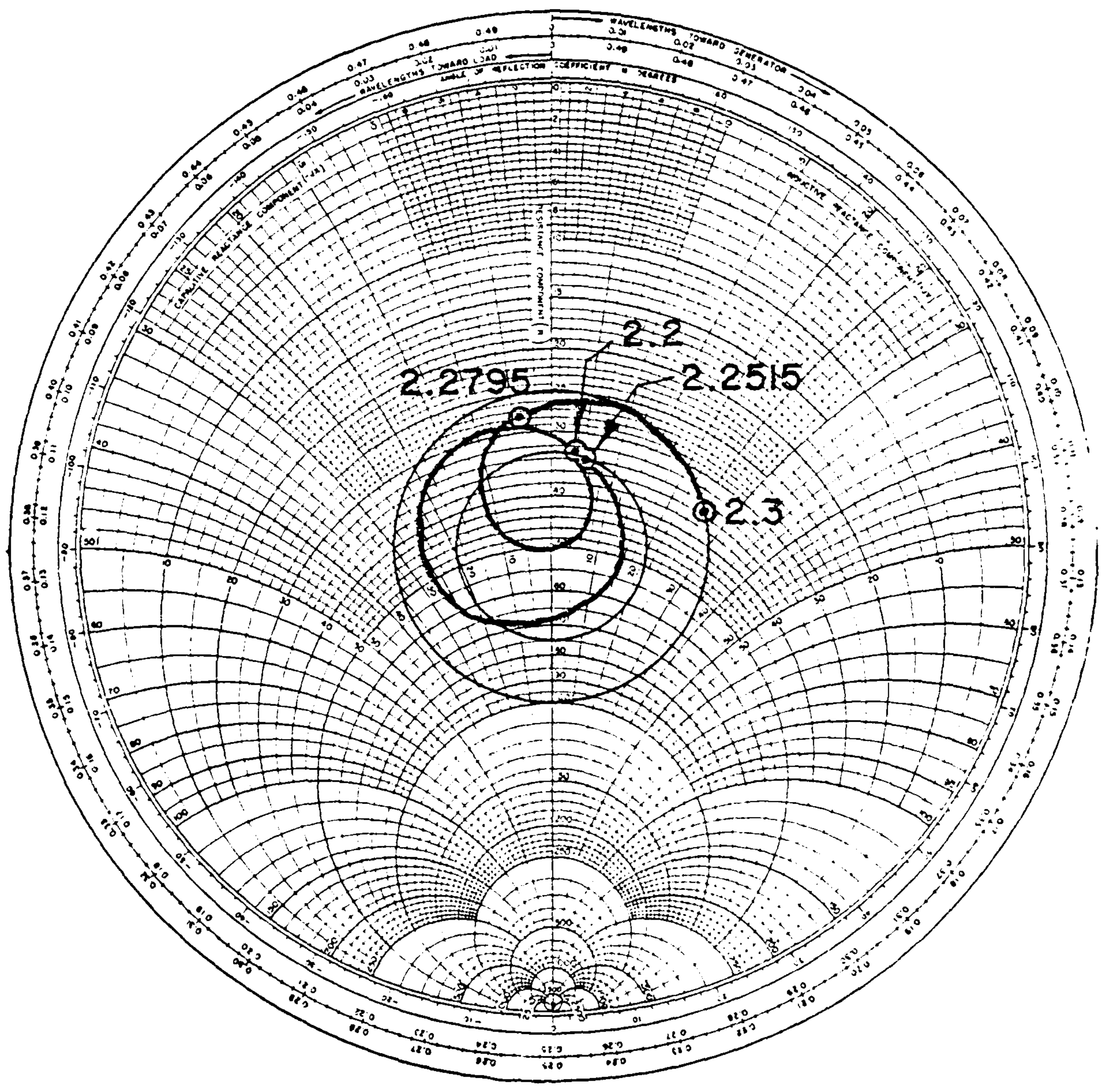


Figure 23. Impedance versus frequency curve for the Model 55.2005 array.

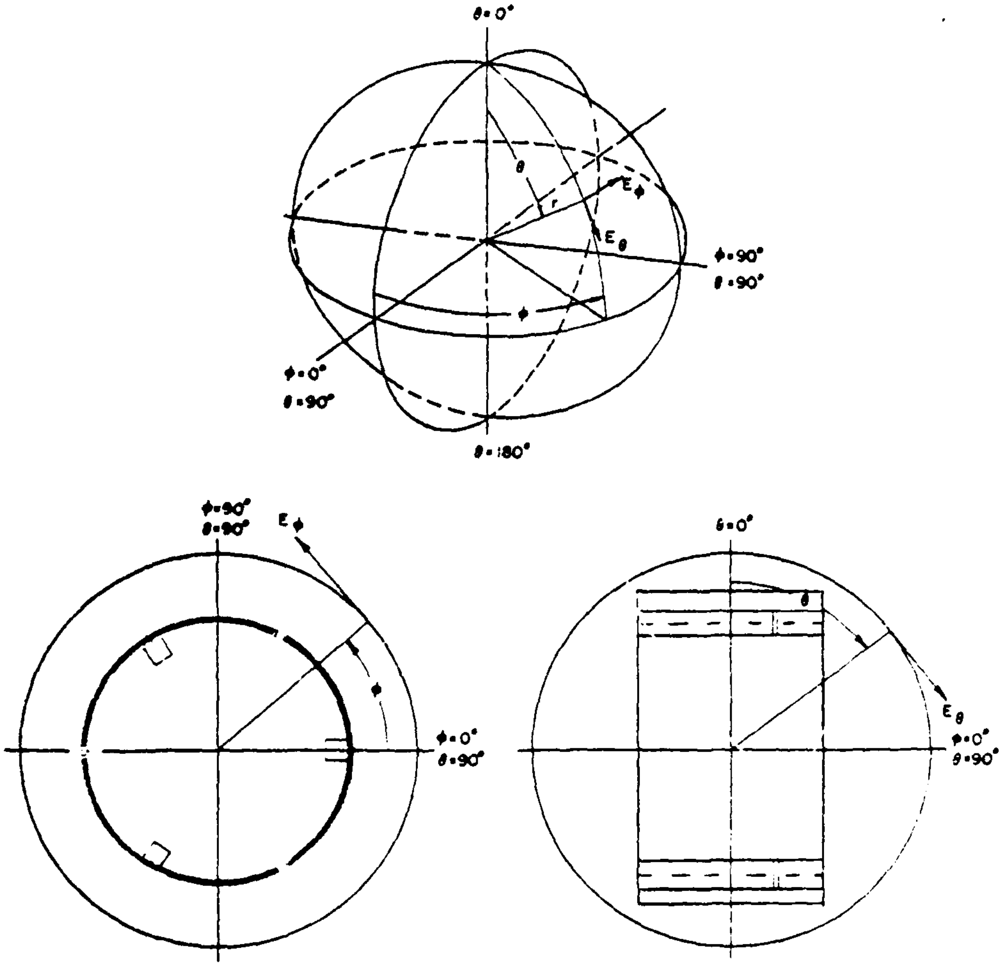


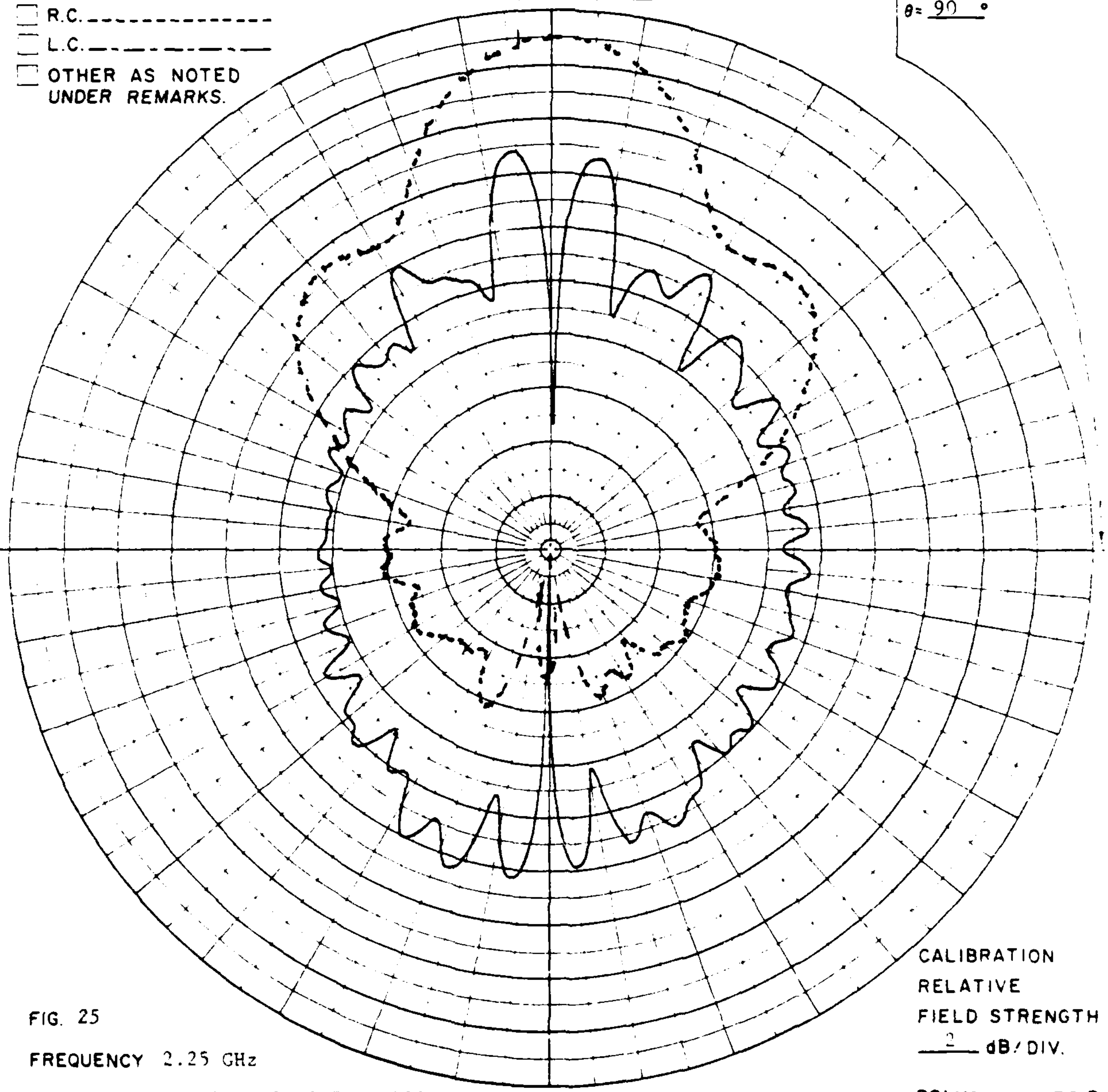
Figure 24. Coordinates for the Model 20.005 pattern measurement.
Range Request No. 2468.

POLARIZATION

- [XX] GAIN REF.
- [XX] Eθ
- [ ] Eφ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED UNDER REMARKS.

φ= ____ ° θ= 0 ° COORDINATE REFERENCE

φ= 0 °
θ= 90 °



CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

FIG. 25

FREQUENCY 2.25 GHz

ANTENNA Model 55.2005 SN AD482, AD483, AD484

REMARKS With Extension
Ref. Antenna SGH 1.7, gain is +16 dB

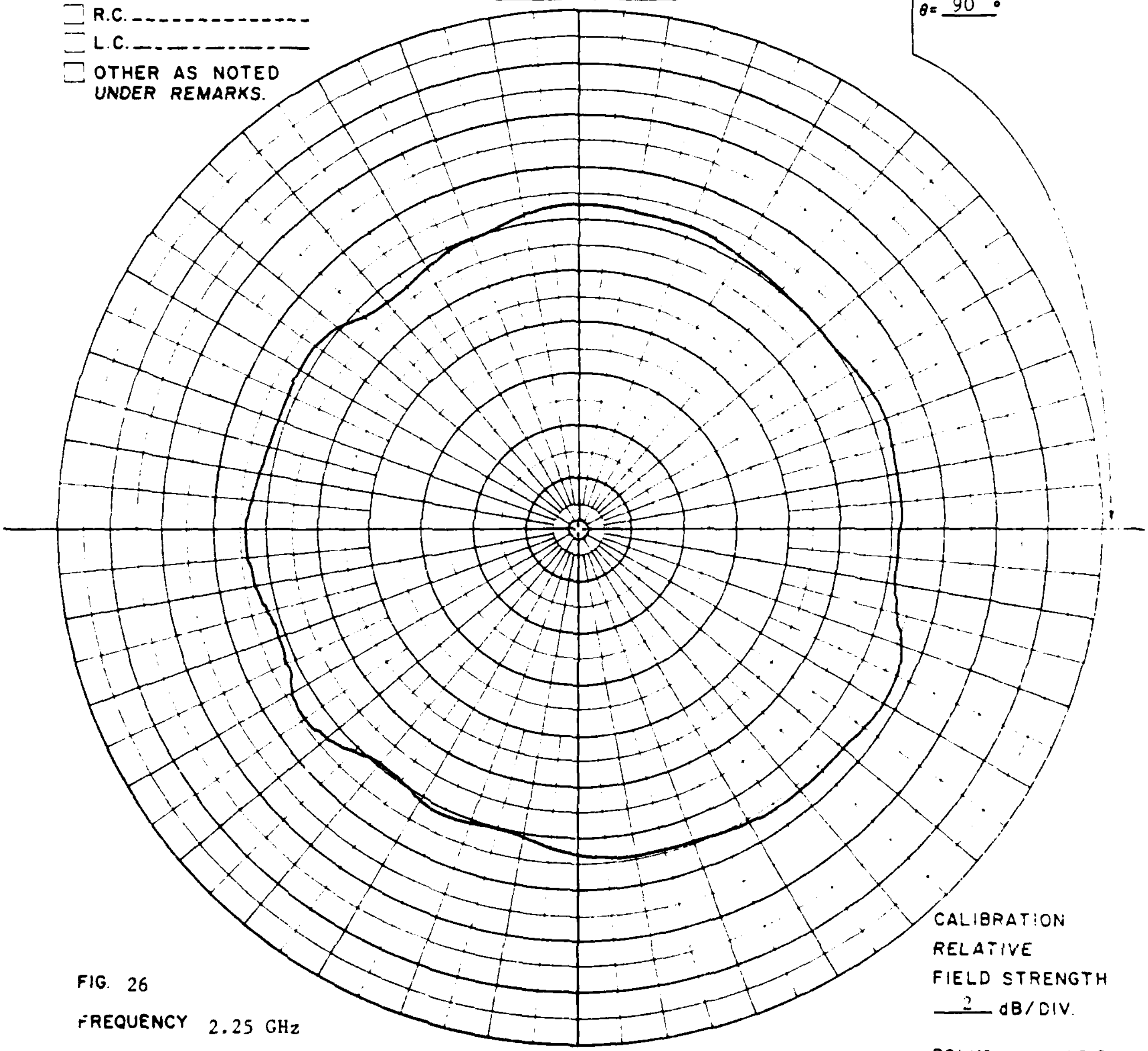
PSL № 12179 B
R. R. 2468

POLARIZATION

- [ ] GAIN REF
- [X] Eθ
- [ ] Eϕ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED *UNDER REMARKS.*

ϕ = 0 °   θ = 90 °   COORDINATE REFERENCE

ϕ = 90 °
θ = 90 °



CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

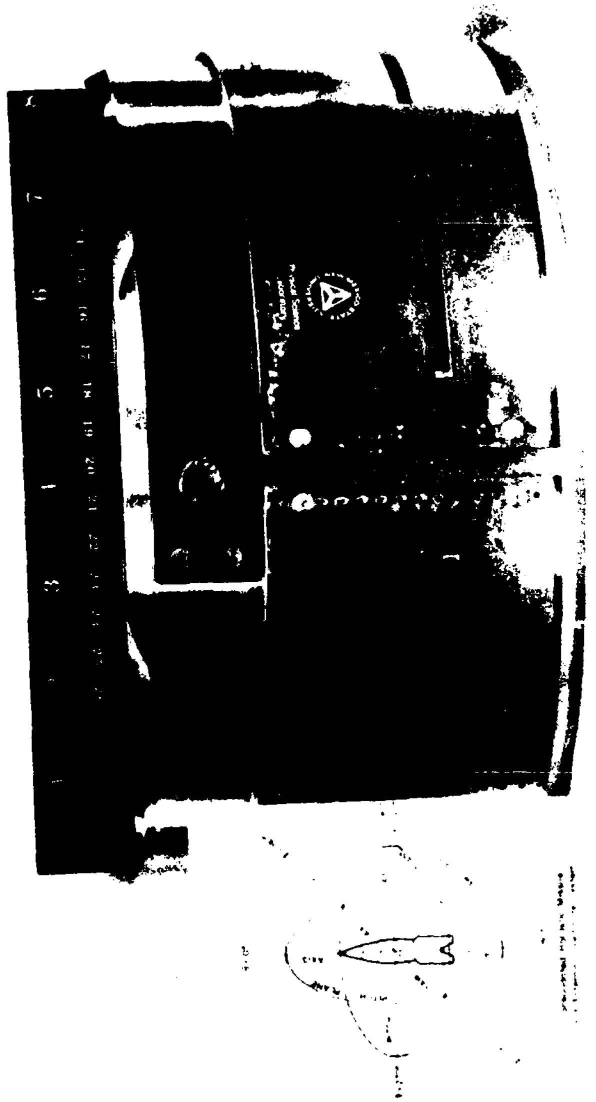
FIG. 26

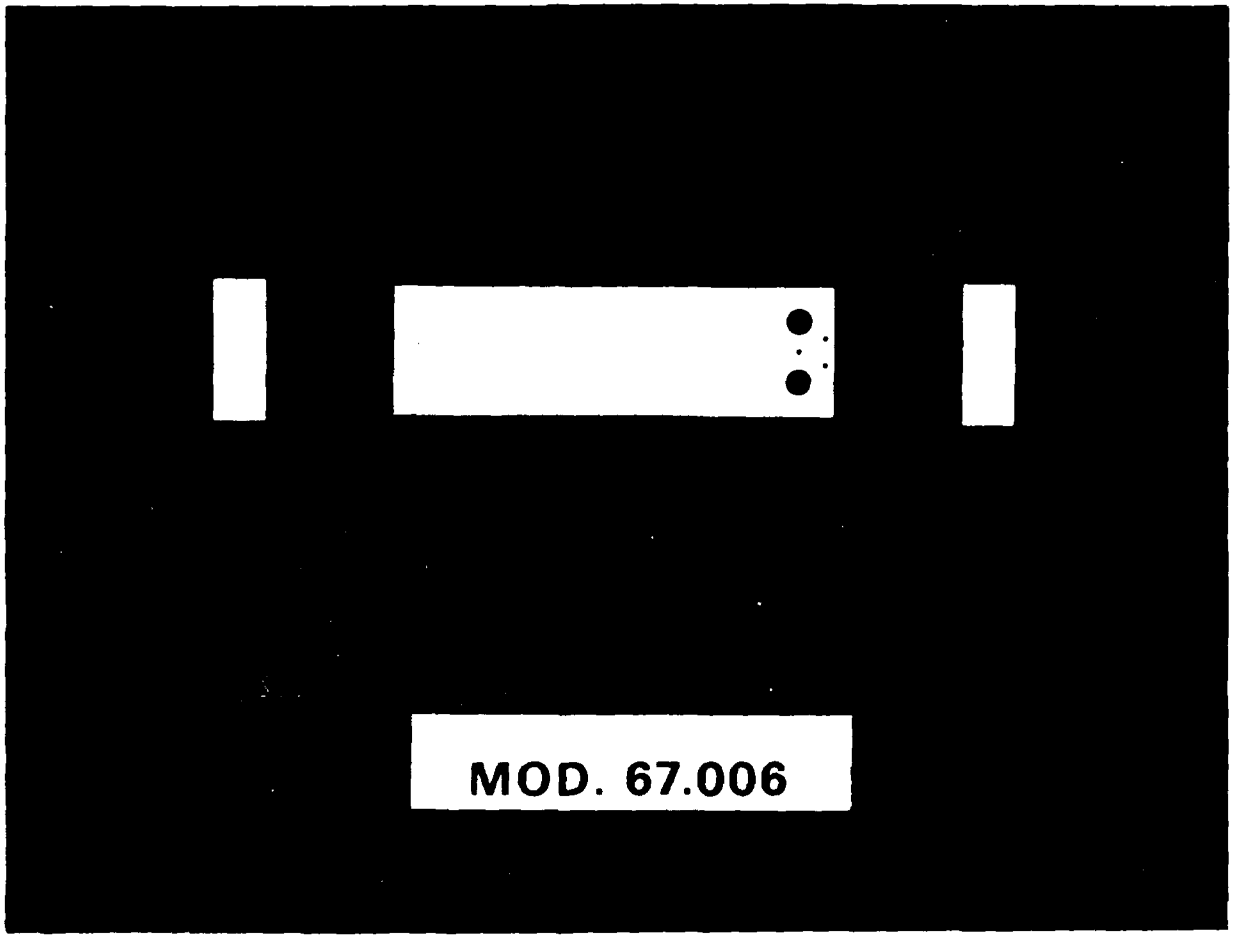
FREQUENCY 2.25 GHz

ANTENNA Model 55.2005 SNAD482, AD483, AD484

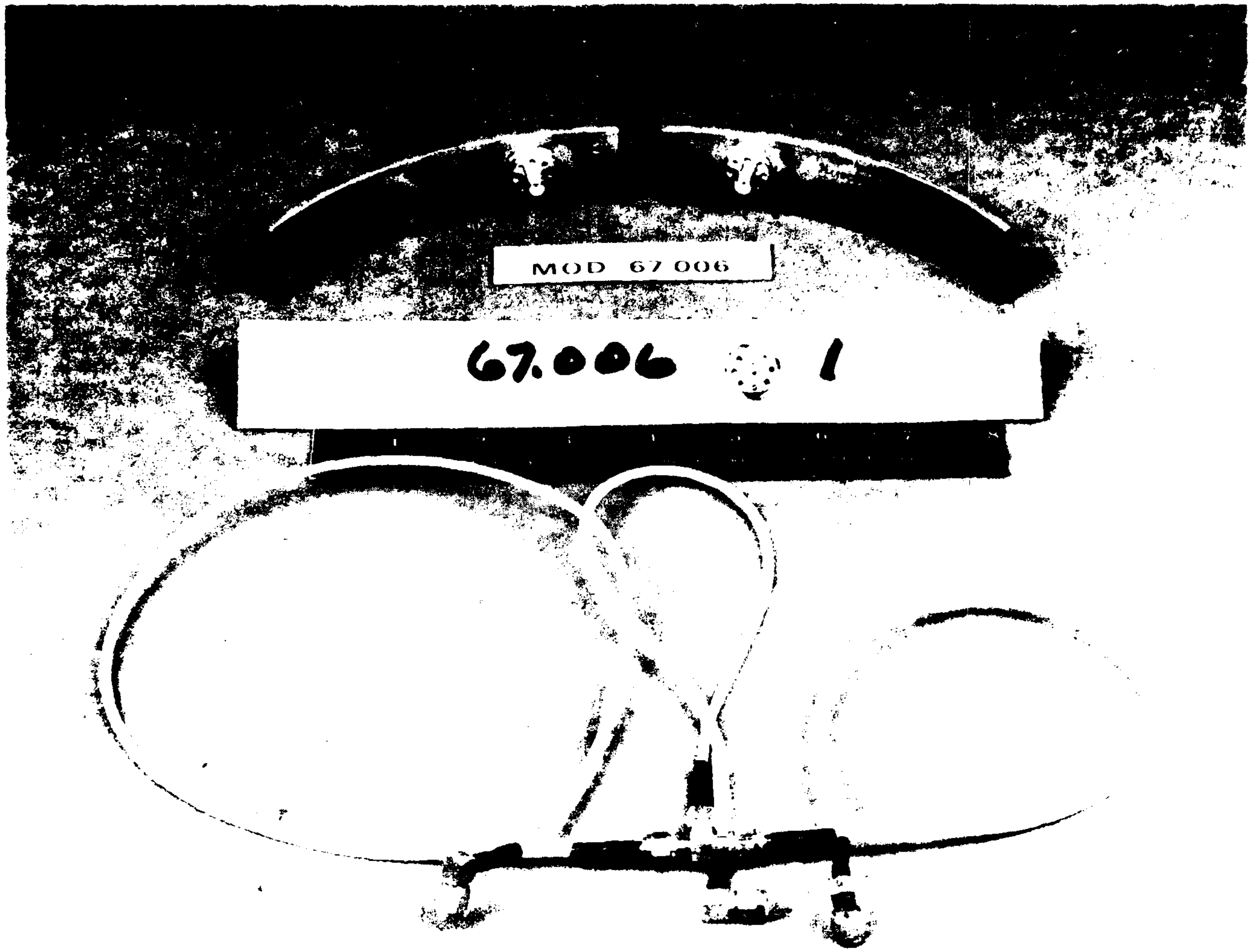
REMARKS

PSL № 12185 B
R. R. 2468





[illegible]. Exploded view of the Model 67.006 Antenna.


MOD 67 006
67.006 1

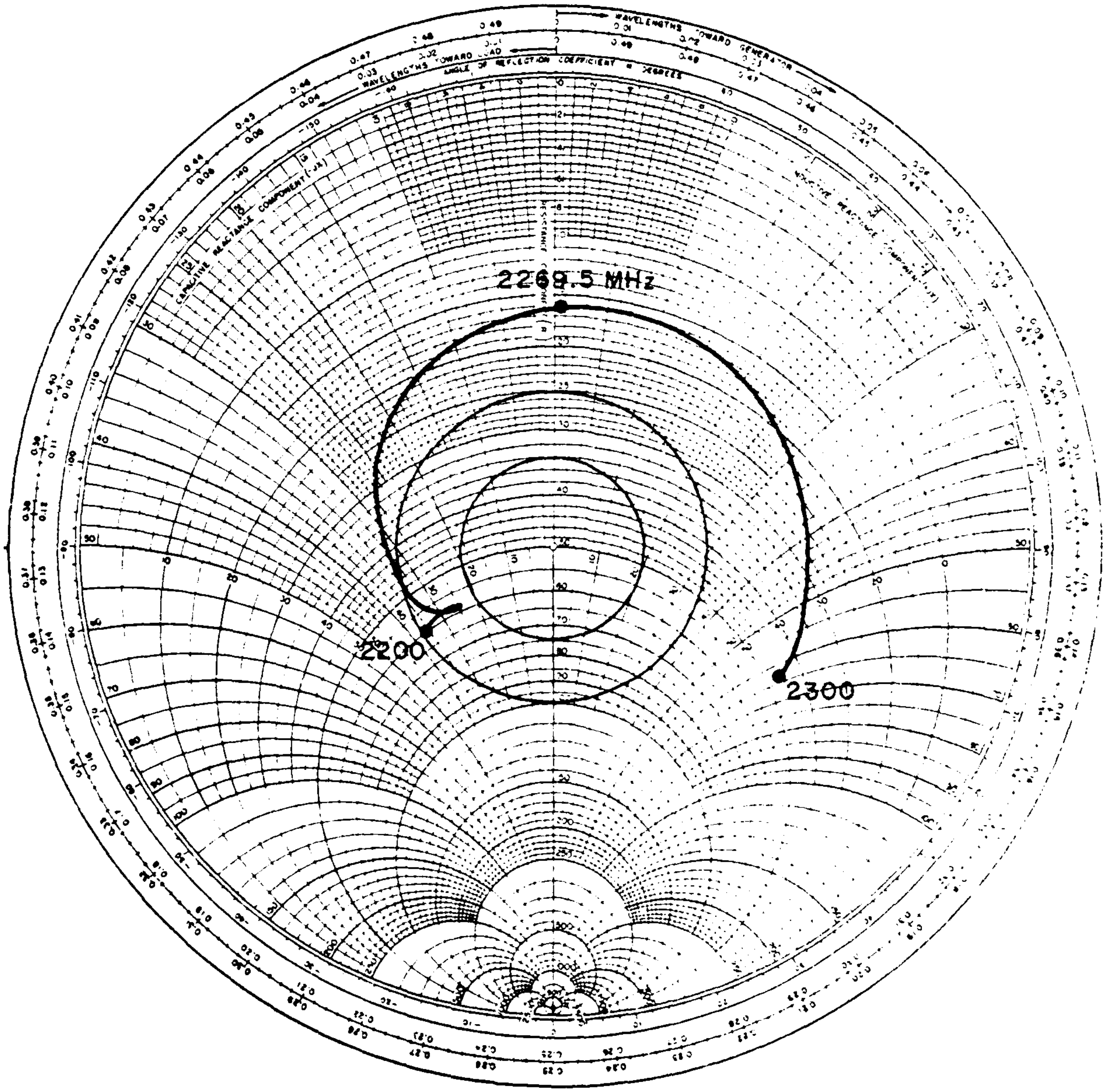


Figure 31. Impedance versus frequency curve of the [illegible] Antenna.

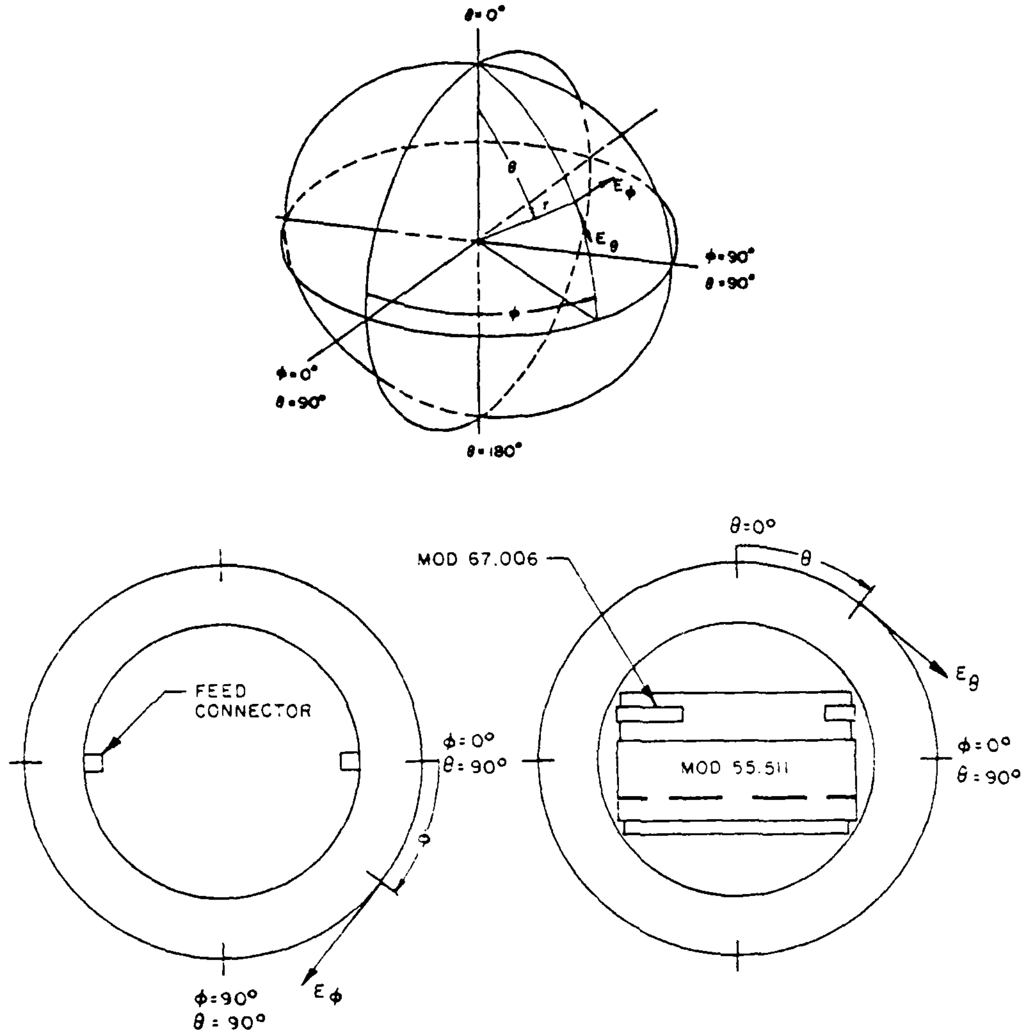


Figure 32. Coordinates for the pattern measurements of the Model 55.511 and Model 67.006 antennas.

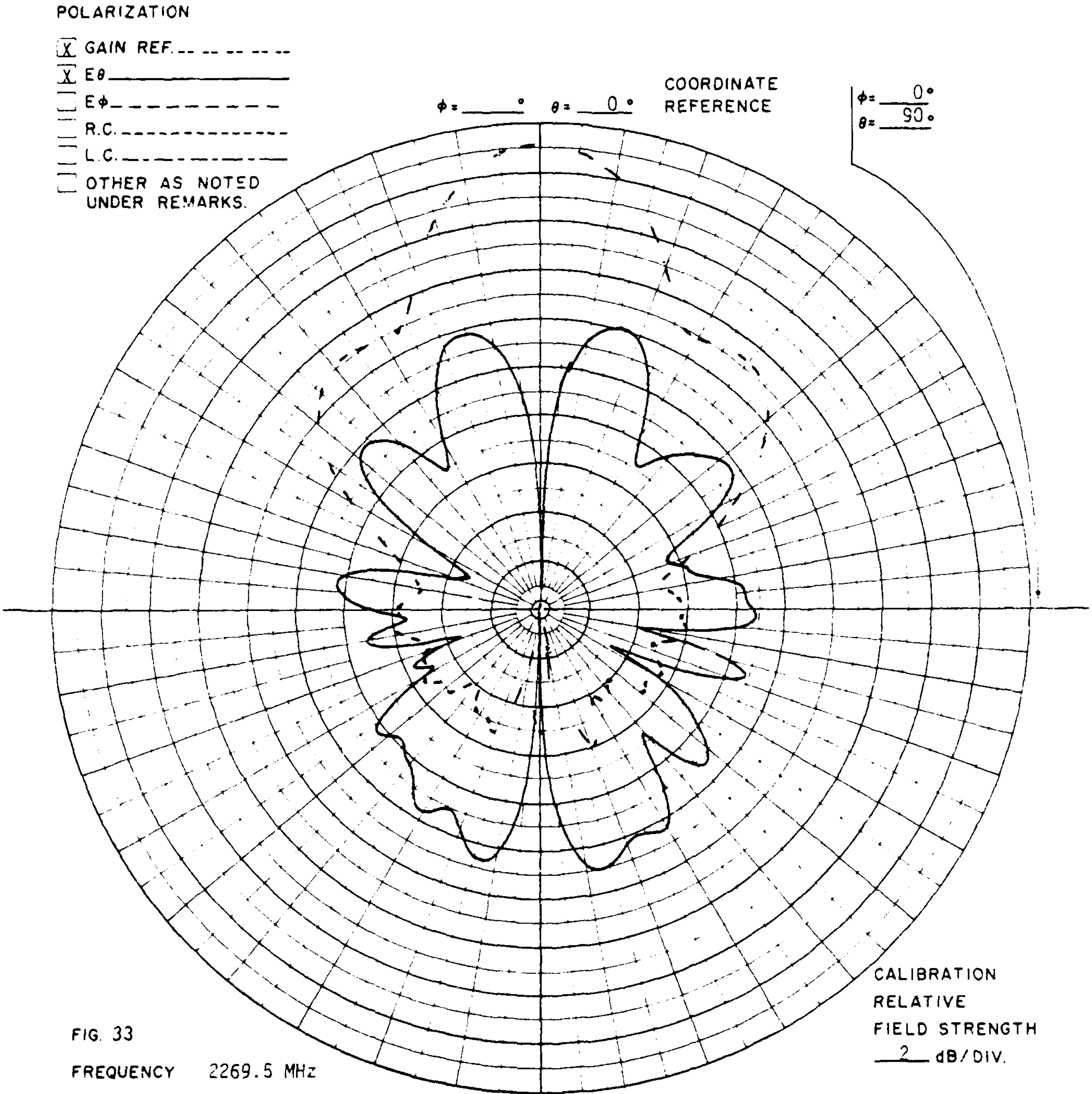


FIG. 33

FREQUENCY 2269.5 MHz

ANTENNA Model 55.511 (10.12" diameter sphere)

REMARKS The gain of the reference antenna (SGH 1.7) is 16 dBi.

PSL № 17301B

RR 2581

POLARIZATION

[X] GAIN REF.

[X] Eθ

[ ] Eφ

[ ] R.C.

[ ] L.C.

[ ] OTHER AS NOTED UNDER REMARKS.

COORDINATE REFERENCE

φ = 0° θ = 90°

φ = 90°
θ = 90°

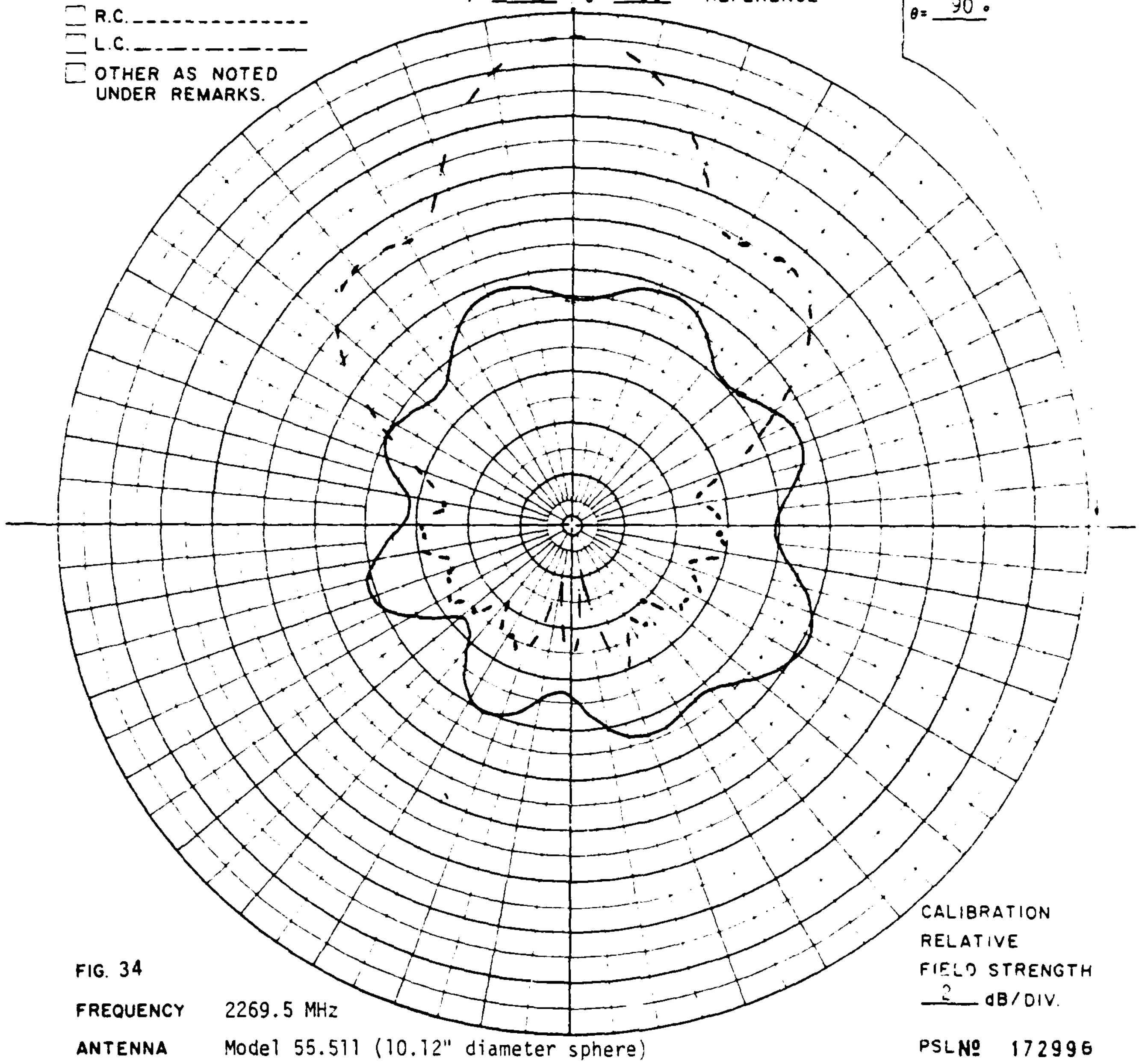


FIG. 34

FREQUENCY 2269.5 MHz

ANTENNA Model 55.511 (10.12" diameter sphere)

REMARKS

CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

PSL№ 172996
RR 2561

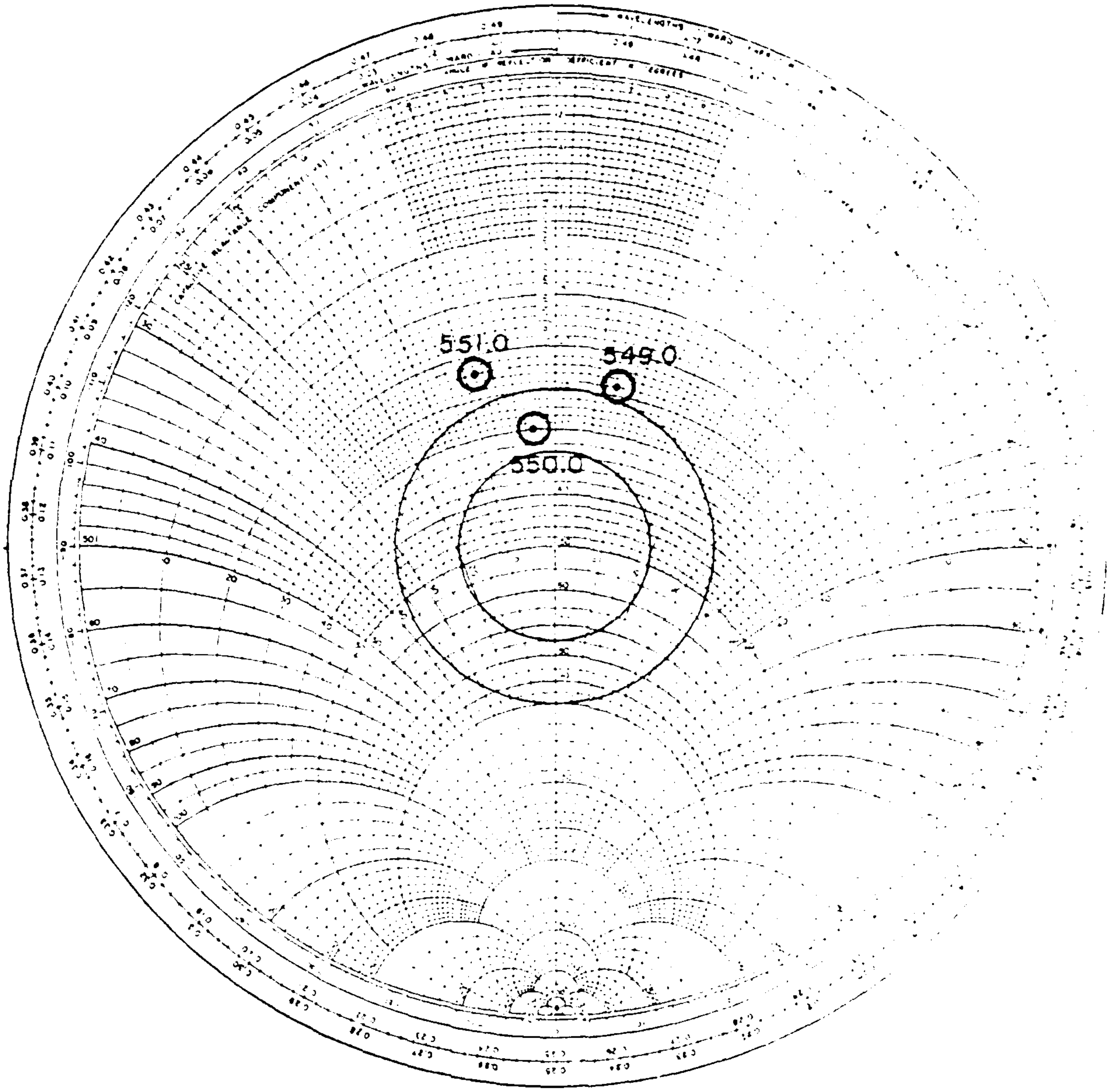


Figure 35. Impedance versus frequency curve for the Model [illegible] antenna array.

POLARIZATION

X GAIN REF.

Eθ

X Eϕ

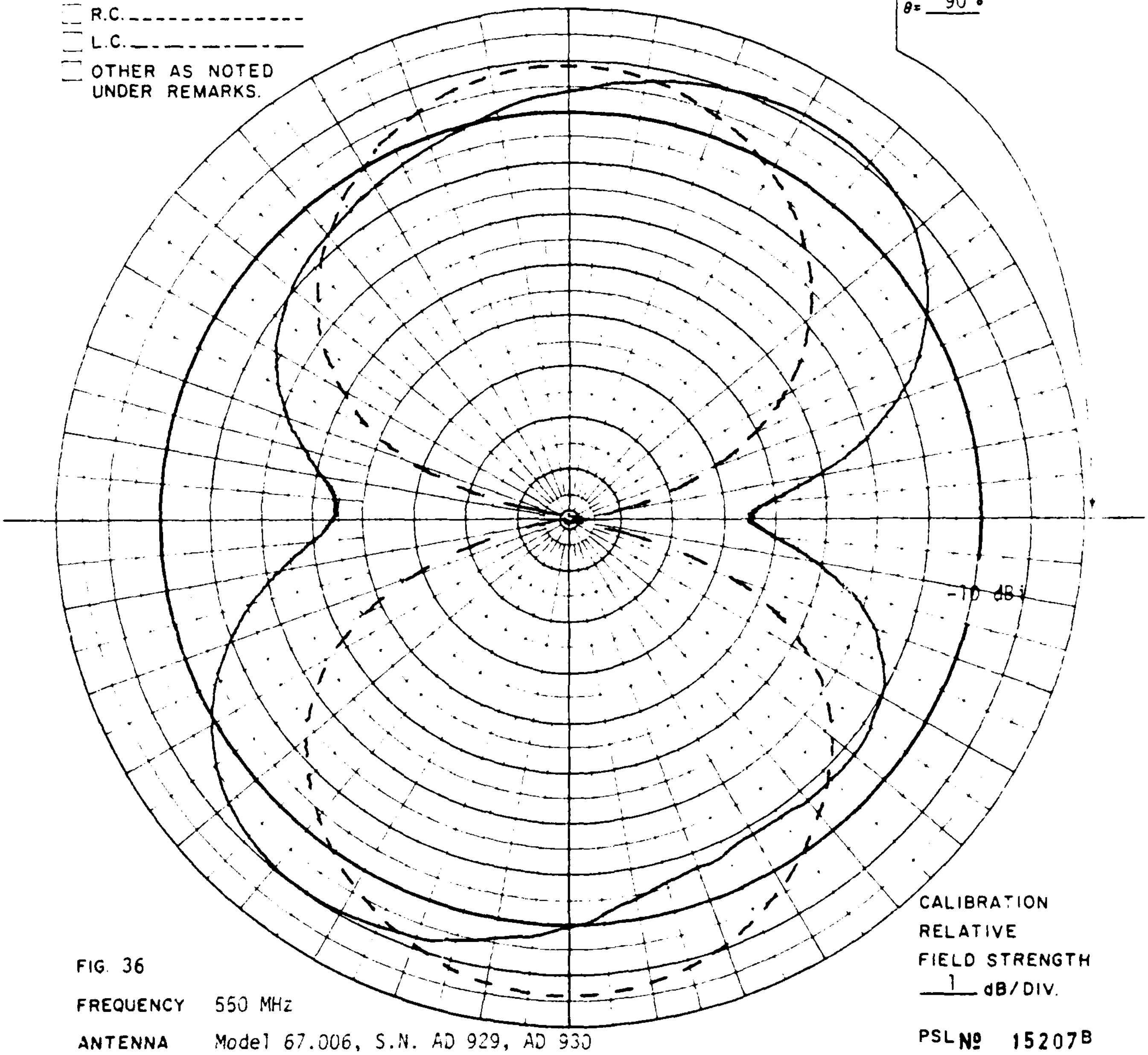
R.C.

L.C.

OTHER AS NOTED UNDER REMARKS.

ϕ = 0° θ = 90° COORDINATE REFERENCE

ϕ = 0° θ = 90°



CALIBRATION RELATIVE FIELD STRENGTH 1 dB/DIV.

FIG. 36

FREQUENCY 550 MHz

ANTENNA Model 67.006, S.N. AD 929, AD 930

REMARKS The gain of the reference antenna (Stoddart dipole) is 2 dBi. Ten dB attenuation was added to the reference antenna. The -10 dBi reference circle is for the test antenna only.

PSL № 15207B

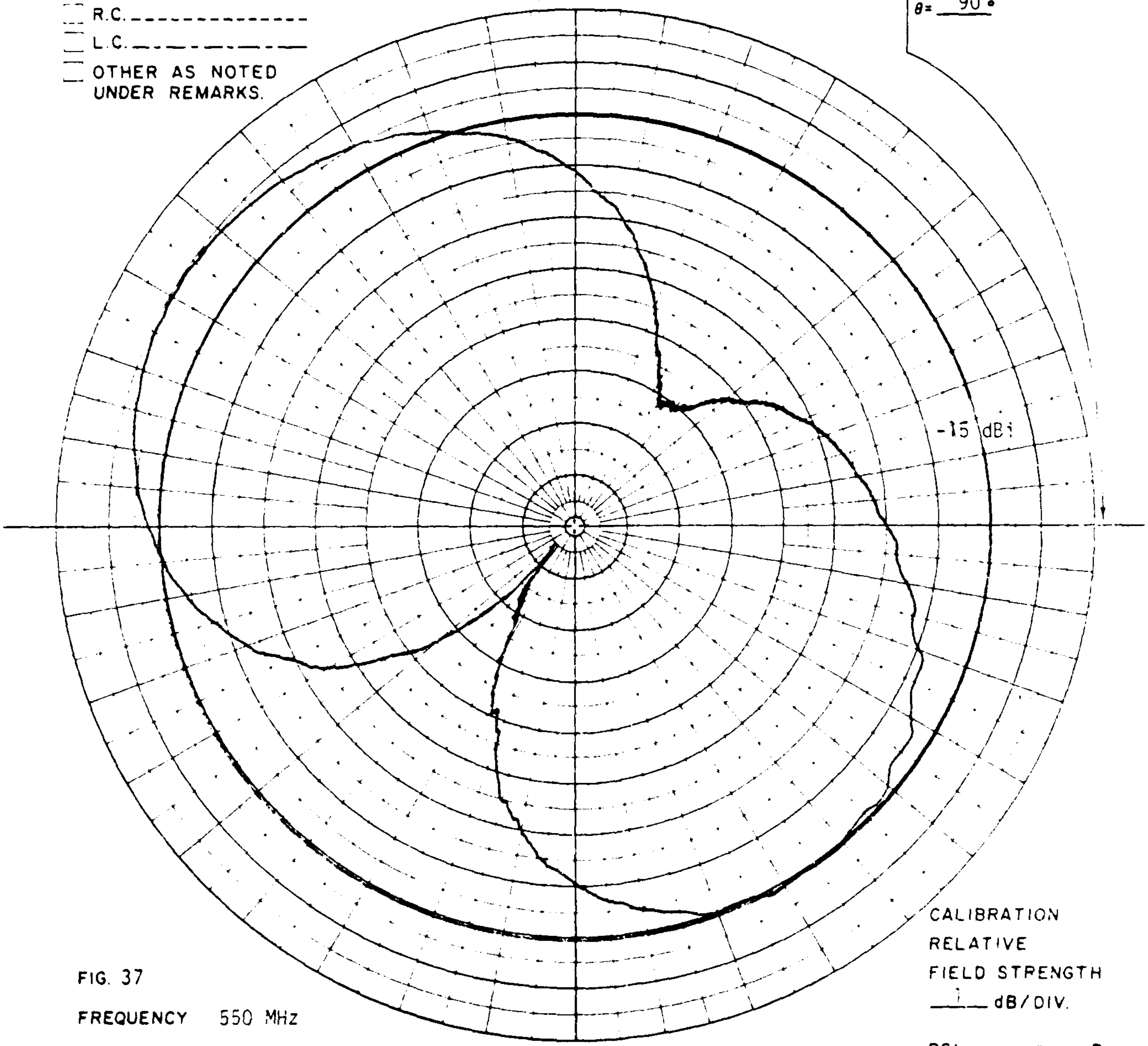
RR 2573

POLARIZATION

- [ ] GAIN REF.
- [X] Eθ
- [ ] Eφ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED UNDER REMARKS.

φ = 0° θ = 90° COORDINATE REFERENCE

φ = 0°
θ = 90°



CALIBRATION
RELATIVE
FIELD STRENGTH
1 dB/DIV.

FIG. 37

FREQUENCY 550 MHz

ANTENNA Model 67.006, S.N. AD 929, AD 930

REMARKS

PSL № 15210B

RR 2573

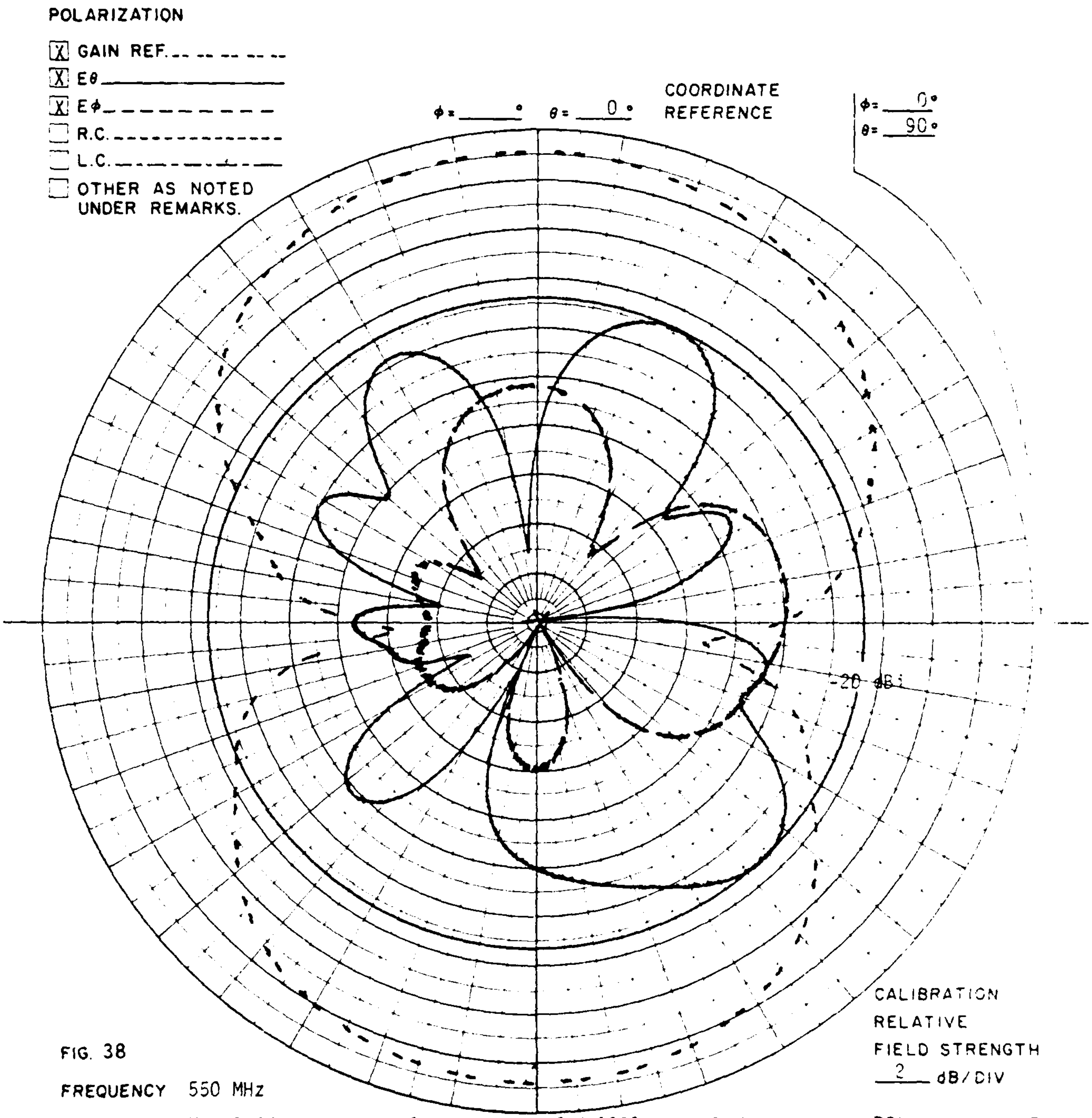


FIG. 38

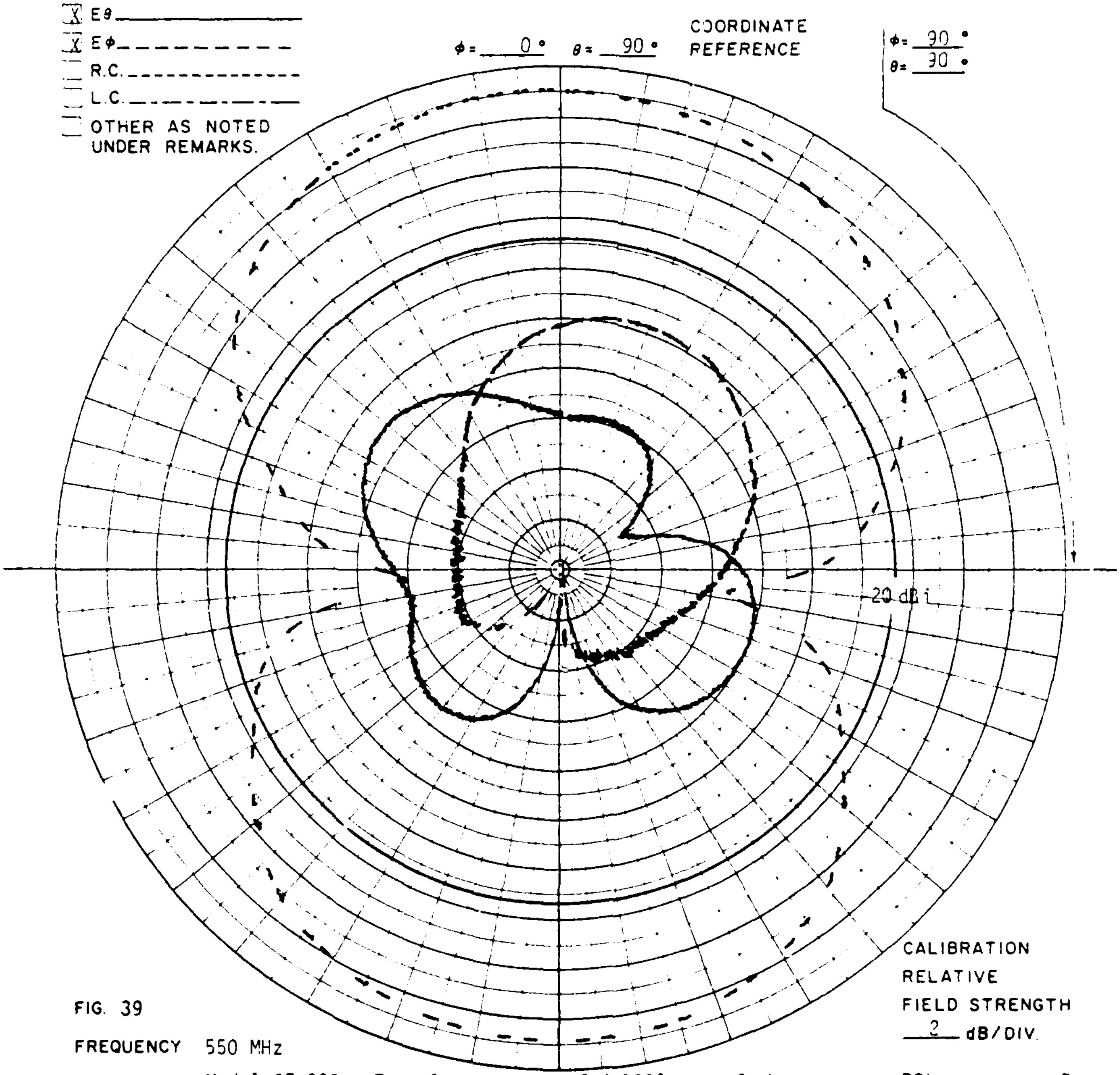
FREQUENCY 550 MHz

ANTENNA Model 67.006. Two element array fed 180° out of phase. **PSL Nº 17429B**

REMARKS The gain of the reference antenna (Stoddart dipole) is +2 dBi. RR 2576
Ten dB attenuation was placed in line with the reference antenna. The Model 67.006 radiates through a 1 x 3/8 inch slot in the metallic nose cone.

POLARIZATION

- [X] GAIN REF.
- [X] Eθ
- [X] Eϕ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED UNDER REMARKS.



CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

FIG. 39

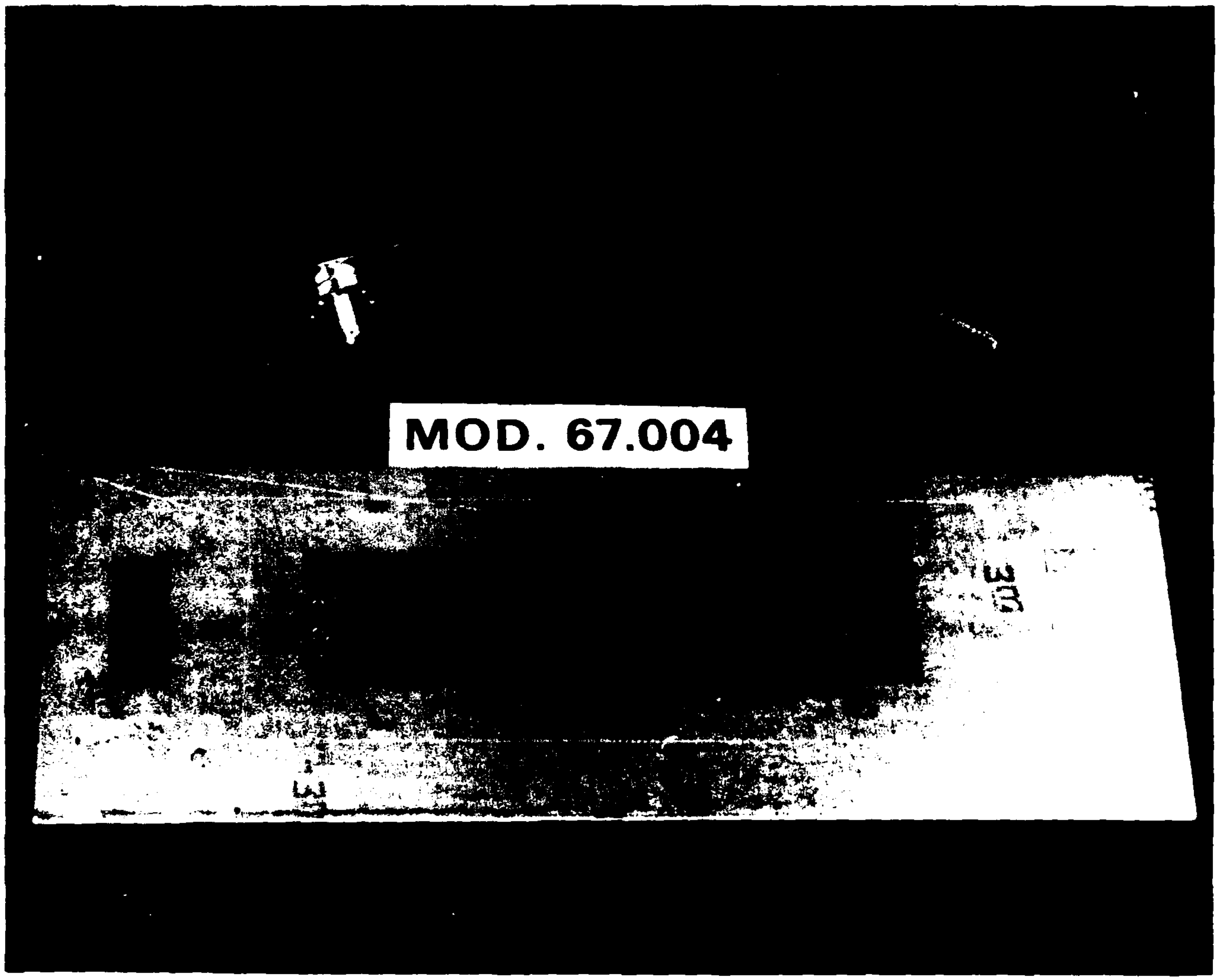
FREQUENCY 550 MHz

ANTENNA Model 67.006. Two element array fed 180° out of phase.

REMARKS The gain of the reference antenna (Stoddart dipole) is +2 dBi. Ten dB attenuation was placed in line with the reference antenna. The Model 67.006 radiates through a 4 x 3/8 inch slot in the metallic nose cone.

PSL № 17428B

RR 2576



[illegible] Exploded View of the Model 67.004 Antenna.

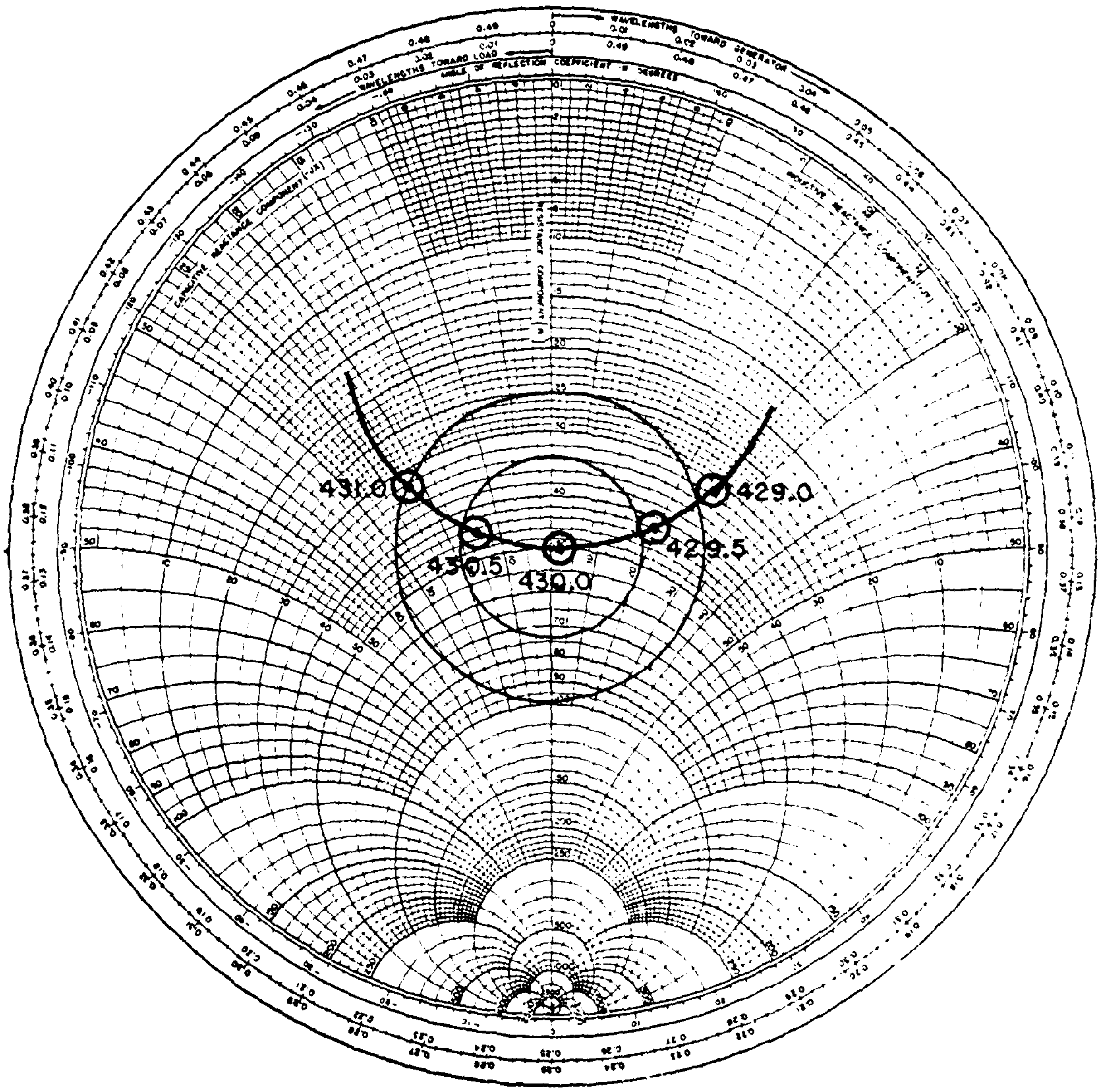


Figure 41. Impedance versus frequency curve for the Model 67.004 antenna array.

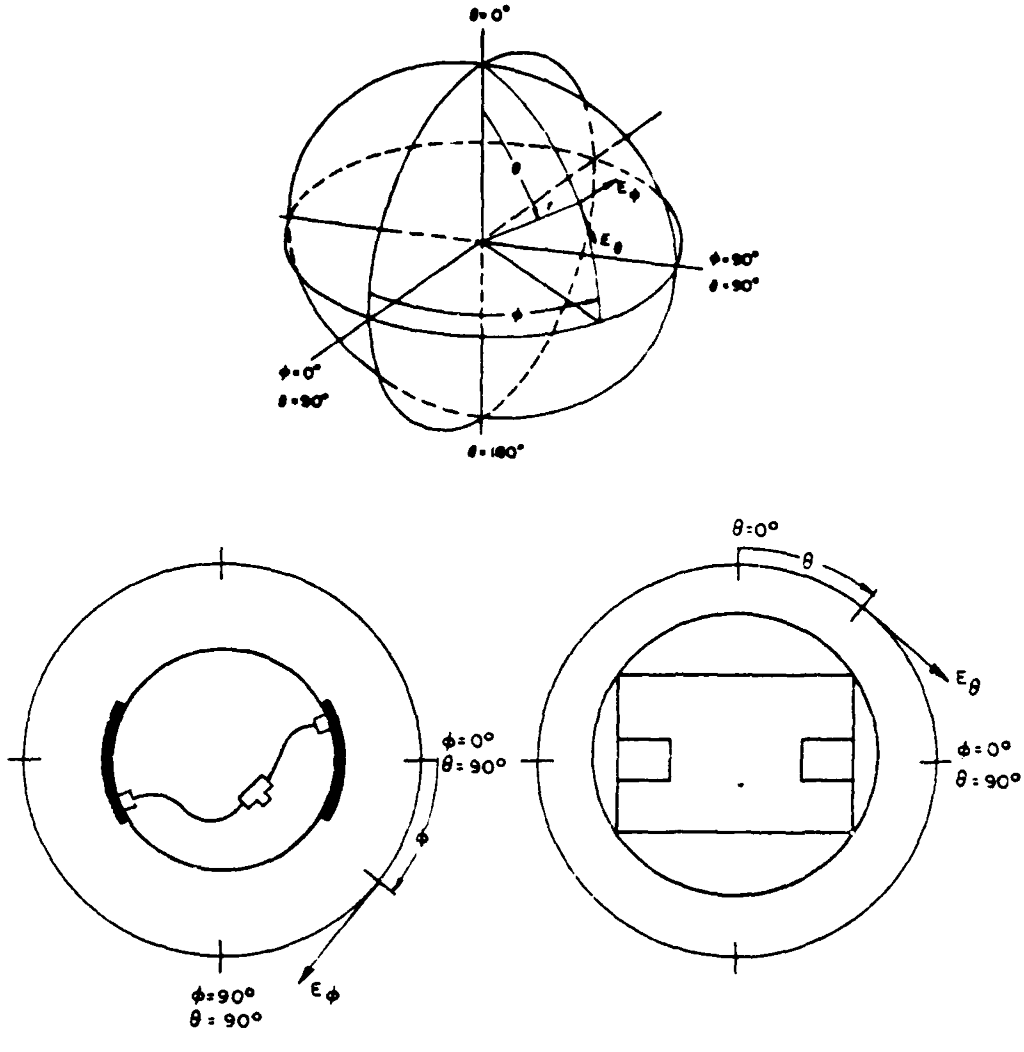


Figure 42. Coordinates for the Model 67,004 Stripline 409 Mhz. Antenna. Range Request 2421.

POLARIZATION

- X GAIN REF. ---------
- X $E\theta$ ______
- X $E\phi$ ---------
- R.C. ---------
- L.C. ---------
- OTHER AS NOTED UNDER REMARKS.

ϕ = ____ ° θ = 0 ° COORDINATE REFERENCE

ϕ = 0 °
θ = 90 °

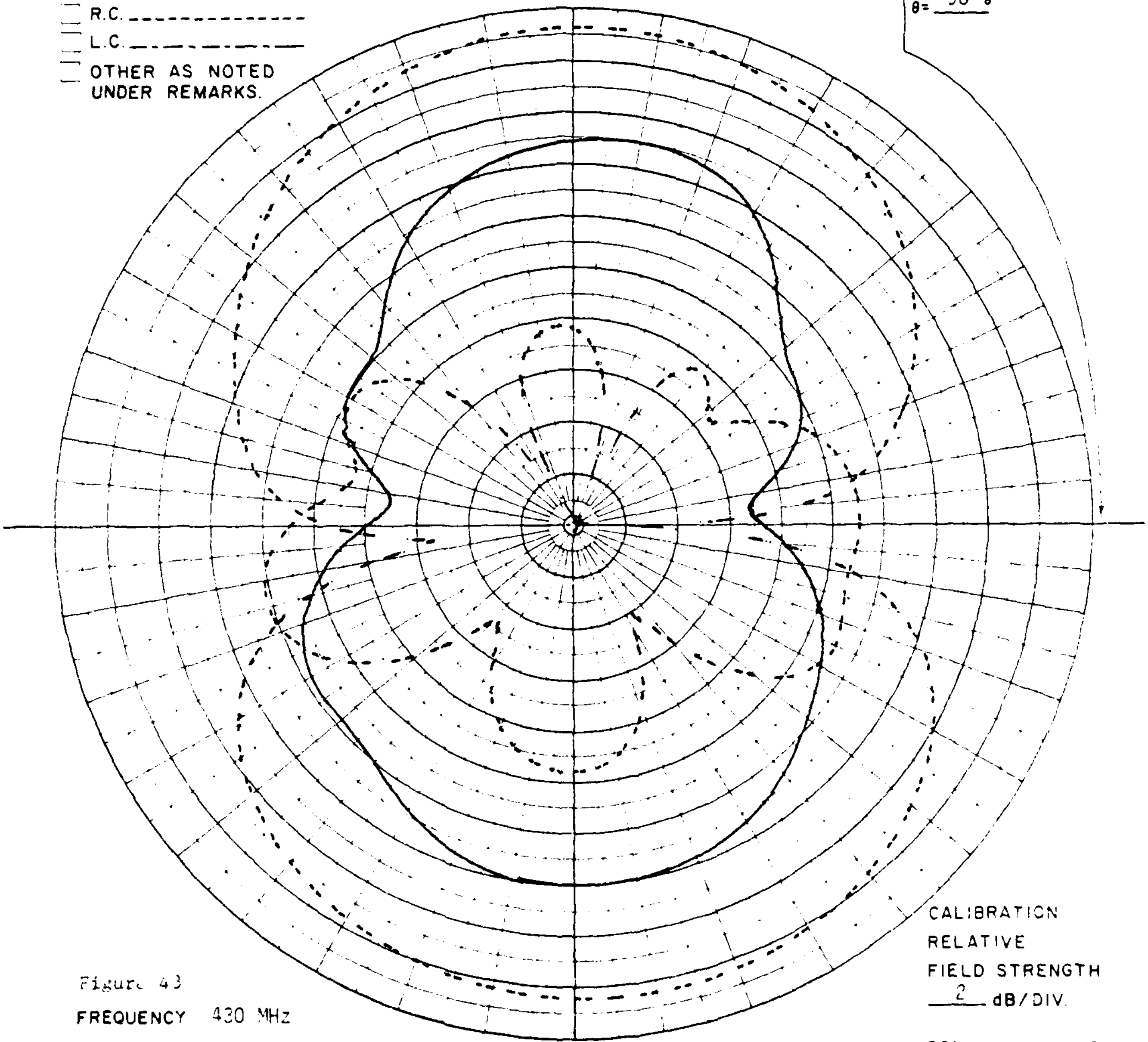


Figure 43

FREQUENCY 430 MHz

ANTENNA Model 67.004

REMARKS Gain of Reference Dipole is +2dBi

CALIBRATION
RELATIVE
FIELD STRENGTH
2 dB/DIV.

PSL№ 12891B

POLARIZATION

- [ ] GAIN REF.
- [x] Eθ
- [x] Eφ
- [ ] R.C.
- [ ] L.C.
- [ ] OTHER AS NOTED UNDER REMARKS.

φ = 0 ° θ = 90 ° COORDINATE REFERENCE φ = 90 ° θ = 90 °

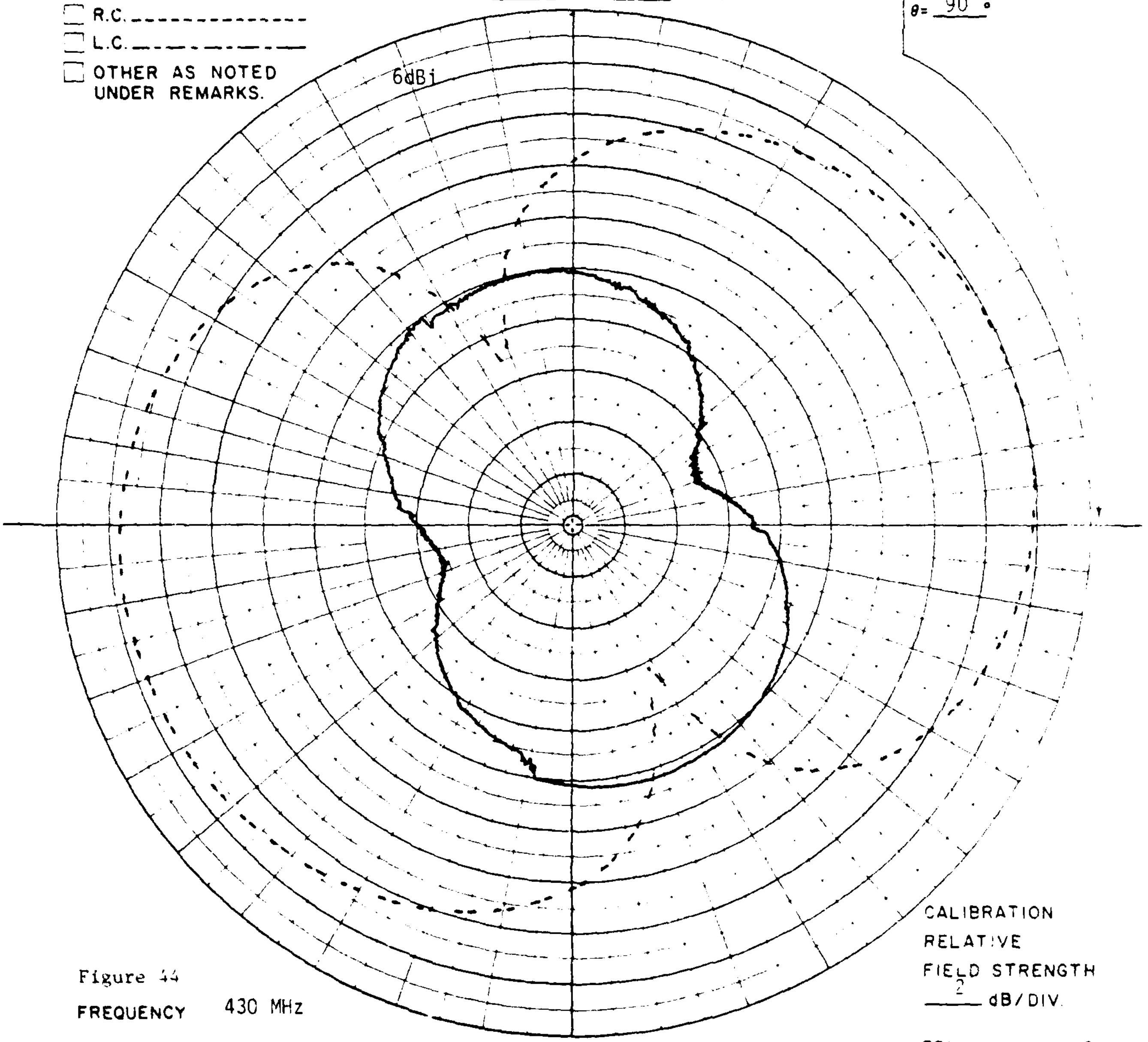


Figure 44

FREQUENCY 430 MHz

ANTENNA Model 67.004

REMARKS Reference PSL 12891B

CALIBRATION RELATIVE FIELD STRENGTH 2 dB/DIV.

PSL № 12896 B

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Appendix B

MODEL	ELEM PER SUBA.	NUMBER OF SUBA.	VEHICLE DIA (INCHES)	MOUNTING	REFERENCE QUARTERLY REPORT NO.	ANTENNA SERIAL NO.	RANGE REQUEST NO.	FIRST VEHICLE	REMARKS
55.205	8	2½	17.2	F	4			Second Vehicle A18.805	
55.1405	8	2	14	F	8, 9, 10 11	AD909 AD910	2549	A13,030 AURORAL E TLM	
55.1505	8	2	15	F	2, 3, 4, 5 6, 9, 10, 11	AD913 AD914	2550	A31,701 ASTROBEE F	
55.1705	8	2	17.25	F	7, 8				
55.2005	8	3	20.75	F	4, 5, 6	AD482 - AD487	2583 2468	A44.651-1 ZIP	2 arrays on the extension
67.004					7, 8				Quadraloop 430 MHz
67.006					9, 10, 11				Quadraloop 550 MHz

F - Flush, I - Internal

ANTENNAS DEVELOPED UNDER CONTRACT F19628-78-C-0052

Appendix C

ANTENNAS SHIPPED

Model	Vehicle
2.007	A44.6S1-1 ZIP
2.042	FLT #I830.09-1A
2.042	A10.82-1 A10.802-2
2.042	A30.072
2.042	242 MHz
4.003	Aries
4.003	A04.606-1
4.003	TEM-2B A24.609-3
4.003	A24.651-1
4.003	A24.7S2-2
4.003	44.28" Diameter
6.010	A04.606-1
6.017	MSMP/SPICE Drop Test
6.017	A24.7S2-2 FRISSE
6.017	44.28" Diameter
6.060	FLT #I830.09-1A
6.060	FLT #A07.712-2
6.060	FLT #A10.802-1 #A10.802-2
6.060	A30.072
6.060	A10.901-1 A10.901-2
6.060	A12.9A2
6.060	A11.074
6.060	A30.073

ANTENNAS SHIPPED

Model	Vehicle
6.060	A13.020
6.060	A13.030
6.060	A13.031
6.060	A10.903
7.015	A44.6S1-1 ZIP
7.015	A24.651-1
7.015	A24.7S2-2
7.015	44.28" Diameter
7.016	A08.708-1 A08.708-2
7.016	A31.702
7.016	A08.705-2
7.016	A18.805
23.020	A08.708-1 A08.708-2
23.020	FLT #1830.09-1A
23.020	FLT #A07.712-2
23.020	FLT #A10.802-1 #A10.802-2
23.020	A12.9A2
23.020	A18.805
23.020	A11.074
23.020	A30.072
23.020	550 MHz
23.020	A30.073
23.020	A13.020
23.020	A13.030

ANTENNAS SHIPPED

Model	Vehicle
23.020	A13.031
23.020	A10.903
23.021	A44.6S1-1 ZIP
39.003	Aries X-Band
39.003	TEM-2B A24.609-3
55.205	A31.702
55.205	A18.805
55.205	A30.072
55.205	A30.703
55.380	A24.752-1
55.380	IRBS
55.380	A24.651-1 ZIP-1
55.380	A24.7S2-2 FIRSSE
55.385	ARIES
55.385	TEM-2B A24.609-3
55.385T	
55.455	FLT Housings
55.455	A10.802-1 A10.802-2
55.455	RADC-5
55.455	RADC-6 RADC-7
55.505	A10.903
55.510	AC15
55.510C	10" Sphere

ANTENNAS SHIPPED

Model	Vehicle
55.510C	10" Sphere
55.511	A08.706-2, 10" Sphere
55.511	10" Sphere
55.511	10" Sphere
55.511	AC-15
55.511	AC-14 A10.903, 2269.5 MHz
55.805	A08.708-1 A08.708-2
55.805	A08.705-2
55.805	A11.074
55.805	A10.901-1 A10.901-2
55.805	A13.020
55.1405	A13.030
55.1405	A13.031
55.2005	A44.6S1-1 ZIP
67.006	AC14, A10.903, 10" Sphere, 550 MHz

Appendix D

CUMULATIVE INDEX FOR THE QUARTERLY PROGRESS REPORTS

QUARTERLY Report No.	
1	Mod. 55.380 for SPICE and IRBS Unit radiator investigation Printed circuit dipole investigation
2	Mod. 55.380 for IRBS Models 55.205 and 55.605 Model 38.031 for the Finch. dia. sphere Layout for a 10 inch dia. sphere Unit radiator investigation Printed circuit dipole investigation.
3	Models 55.205 and 55.605 Models 55.455 and 55.511 Unit radiator investigation MSMP-2 Measurements Printed circuit dipole investigation
4	Model 55.205 Model 55.1505 Model 55.2005 Unit radiator investigation
5	Model 55.205 Model 55.2005 Model 55.455 Model 55.1505 MSMP/SPICE Drop Test
6	Model 55.2005 Model 55.1505 Model 55.205 Unit radiator investigation

7	Model 55.1705
	Model 67.005
	Aries X-Band Tracker
	Unit radiator investigation
	Printed Circuit Antenna Workshop
8	Model 55.1705
	Model 55.1405
	Model 67.004
	Model PD380 power dividers
	MSMP Program (TEM-2B)
	Unit radiator investigation
9	Model 55.1405
	Model 55.1505
	Model 67.006
	MSMP,TECOM Model 106002
	MSMP-2
10	Model 55.1405
	Model 55.1505
	Model 67.006
11	Model 55.1405
	Model 55.1505
	Model 67.006
	Vehicle No. A31.701
	Vehicle No. 10.093
	Vehicle No. A13.030
	Vehicle No. A13.031
12	Aries Vehicle
	Vehicle No A10.903
	Sphere AC-14

Appendix E

PUBLISHED SCIENTIFIC REPORTS AND PAPERS

1. Wilton, R. E. and A. Waterman, "Telemetry Antennas for Large Diameter Sounding Rockets," AFGL-TR-79-0205, Instrumentation Papers #280 United States Air Force, Hanscom AFB, Massachusetts, September 4, 1979.

2. Waterman, A., "Stripline Antenna Development," Proceedings of Workshop on Printed Circuit Antenna Technology, October 17-19, 1979, Physical Science Laboratory, NMSU, Las Cruces, New Mexico.

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